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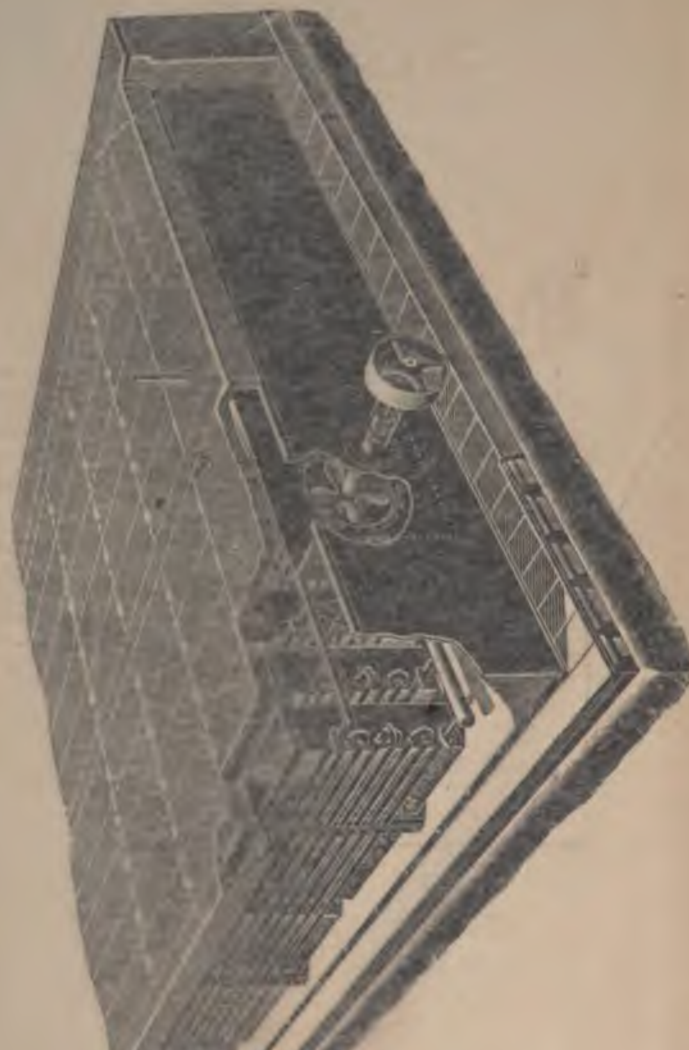
Refrigeration and Ice Making

IN TWO VOLUMES.

VOL. TWO



ICE TANK.

THE THOUGHT IS IN THE QUESTION; THE INFORMATION IS IN THE ANSWER

Audels

ANSWERS

ON

Refrigeration and Ice Making

A PRACTICAL TREATISE

with ILLUSTRATIONS

BY

GIDEON HARRIS, pseud.

and Associates

C. E. Booth

VOL. TWO

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PREFACE TO VOL. II.

It should be understood that the subject matter of this work relates to a growing industry.

Men have died from the extremes of cold and heat, and their lives have been made miserable or happy by a very few degrees variation of the mercurial scale. Hence the power to control an undue rise and fall in temperature may be instrumental in prolonging life and adding to its comfort.

The idea intended to be conveyed is that, in the near future, homes will be cooled in tropical countries, just as they are heated in the north.

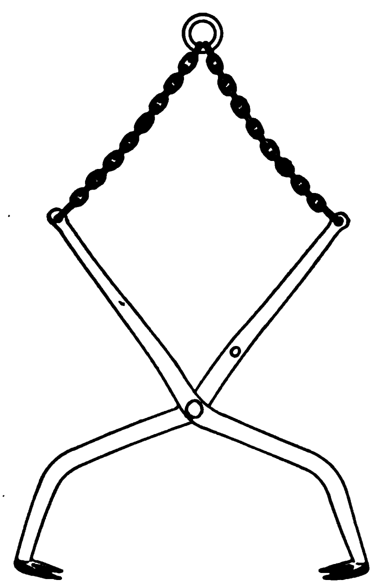
While this humanitarian view of the subject is perhaps the broadest which the subject affords, it is equally true that in a thousand ways in the near future will the control of temperatures influence society, for it would seem that a new factor—refrigeration—is now added to those forces which tend to uplift mankind—and increase not only his comfort, but his power of production.

As by the aid of added heat the human race has made homes amid the ice and snow of the arctic and antarctic regions, so by the aid of artificial refrigeration tropical countries will be brought to the healthful occupation of mankind.

What Herbert Spencer wrote of kindred industries in England may be truthfully be said of the main subject matter of this book-

> "The vital knowledge—that by which we have grown as a nation to what we are, and which now underlies our whole existence, is *a knowledge that has got itself taught in nooks and corners;* while the ordained agencies for teaching have been mumbling little else but dead formulas."
> "That which our school courses leave almost entirely out, we thus find to be that which most nearly concerns the business of life. All our industries would cease, *were it not for that information which men begin to acquire as they best may after their education is said to be finished.* And were it not for this information, that has been from age to age accumulated and spread by unofficial means, these industries would never have existed."

So, while it is well to know what books say about the various processes of an industrial art, it is not the whole story. Actual experience and actual experiment are equally necessary for a sound and masterful acquaintance with the great problem of refrigeration in its application. As Herbert Spencer indicated in the above paragraphs, the steps of advancement may be expected to be taken by practical men.



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CARBONIC ACID SYSTEM.

What other type of compression machine beside the ammonia is used and why?

The Carbonic Acid machine is used very largely in marine service on passenger and freight steamers, war vessels, etc. It is also used to a considerable extent abroad, partly because carbonic acid is made cheaply as a by-product in German breweries; in this country it has found favor, principally in hotels and restaurants, because in case of a leak no harm would be done to perishable goods; then, too, the presence of one-half of one per cent. of ammonia in the atmosphere would be decidedly dangerous, while air containing as high as eight per cent. of carbonic acid could be breathed for a short time without any serious results.

Are most compression plants alike in theory?

The ammonia, sulphurous acid, carbonic acid, ether, and Pictet liquid machines require substantially the same management. The third type, on account of the lack of smell, makes the detection of a leak difficult, but, however, if the joints are smeared with soapsuds a leak may be detected.

What are the important parts of the carbonic acid machine?

The general plan is the same as the ammonia compression plants, that is the main parts are the compressor, condenser and refrigerator.

How does the compressor compare in size with ammonia compressors?

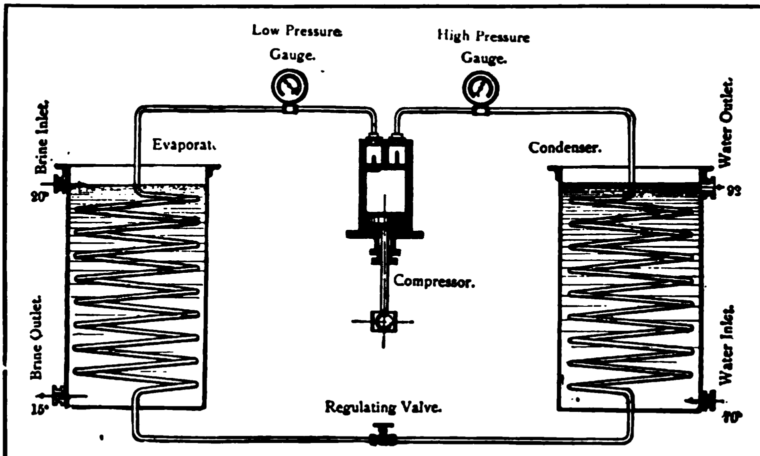
It is considerably smaller, but as it is necessary to carry a very much higher pressure the various parts of the apparatus must be made stronger and heavier.

How is the compressor made ?

It is usually horizontal, except in case of small machines, when it may be vertical. In one leading make it has a jacket through which the return gas passes, which tends to keep the cylinder cool.

How are the compressors built ?

The larger ones are bored out of solid steel forgings ; the smaller ones are cast in a special bronze.



Diagrammatic explanation of a Carbonic Acid Refrigerating machine with brine circulation.

What is frequently done in testing a carbonic acid machine ?

The whole charge is blown into the room, without its harming the workmen, as the carbonic acid being heavier than air tends to drop to the floor.

What very important advantage has a carbonic acid machine in marine service ?

Copper pipes can be used in the condensers.

What is the most marked feature of the carbonic acid system?

The heavy pressure required, varying from 750 pounds in temperate climates, with water at 50 degrees Fahr., to 1,200 pounds in the tropics where water is from 80 to 90 degrees Fahr.

To what degree are carbonic acid machines tested?

Those subject to high pressure are tested to 3,000 pounds hydraulic pressure, and again in warm water, by air, to 1,350 pounds.

On what does the safety of a machine depend?

The safety of any machine does not depend on the pressure at which it works, but on its suitability for the pressure, so that a machine properly constructed for working at even 2,000 pounds per square inch is safer than a machine improperly designed working at only 200 pounds pressure per square inch.

Has a high pressure in this system a compensating feature?

Owing to the non-poisonous nature of the gas, and its low cost, a safety valve may be introduced in the system, which is a desirable feature in any high pressure system.

Where is the use of a carbonic acid machine specially favorable?

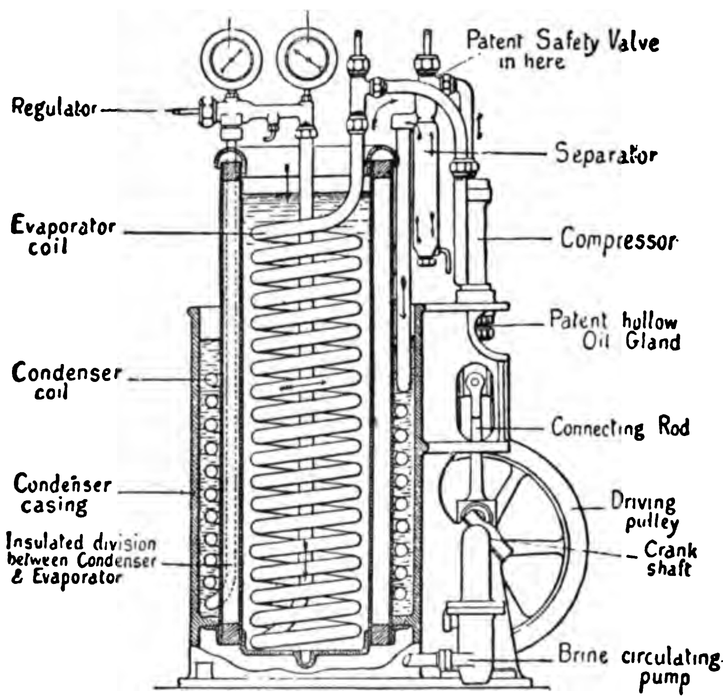
It is the gas that is used for aerating table waters, producing the sparkle in wines, beer, etc., and being perfectly inodorous, cannot under any circumstances taint or damage the most easily affected goods.

What advantage has the carbonic acid machine in the way of condensers?

The condensers are usually of the submerged or open air type, and in marine service copper pipe may be used which is more durable than iron, carbonic acid having no effect on copper.

What is the danger in a leak of carbonic acid?

As it has no odor a leak might not be detected until a workman was so affected by it that he fell to the floor in a faint; as it is heavier than air, this gas also drops to the lower part of the room and the workman might be suffocated if he was alone.



The Hall Marine Carbonic Acid Refrigerating Machine. The compressor is directly attached to the body of the condenser which is of the submerged type.

The cooler consists of a shell concentric with the condenser, well insulated from same, and containing the evaporating coil.

The condenser coil connects with the evaporator coil through the expansion valve shown at the top within easy reach, and each coil is provided with a pressure gauge, the one at the right being the low pressure and at the left the high pressure gauge.

The brine is circulated through the cooler by means of a small brine pump attached to the crank shaft.

How is the Hall stuffing box kept gas tight ?

The compressor gland is made gas-tight by means of cupped leathers on the compressor rod. Glycerine is forced into the space between these leathers at a pressure superior to the greatest pressure in the compressor, so that should a slight leakage take place at the gland it is a leakage of glycerine, either into the compressor or out into the atmosphere, and not a leakage of gas. What little leakage of glycerine takes place into the compressor is advantageous, inasmuch as it in the first place lubricates the compressor, and in the second it fills up all clearances, thereby increasing the efficiency of the compressor. In order to replace the glycerine which leaks out of the lubricator, a small hand pump is provided, a few strokes of which are required every two to four hours.

Describe the safety valve of carbonic acid machines.

In order to open up the compressor for examination of piston and valves, it is necessary to fit a stop valve on both suction and delivery side, so as to confine the carbonic acid to the condenser and evaporator. As the machine might be started again without opening the delivery valve it is necessary to have a safety-valve on the delivery pipe. This is an ordinary spring safety valve, having at its base a thin copper disc, gas-tight and liable to rupture at about 1,350 pounds pressure.

Describe the Evaporator.

It consists of extra heavy iron pipe welded into long lengths inside of which the carbonic acid evaporates. The heat required for evaporation is furnished by brine which surrounds the pipes, or by air, according to which method is used.

How is the flow regulated in carbonic acid machines ?

By a so-called expansion valve between the condenser and evaporator.

What becomes of the glycerine which gets into the compressor ?

The gas as it leaves the compressor passes into a separator where the glycerine impinges against the sides of the vessel and adheres to it as it has no affinity for carbonic acid ; the glycerine then falls to the bottom of the separator and is drawn off from time to time, while the gas passes on into the condenser.

Is a slight leakage objectionable ?

A slight leakage into the compressor would be of advantage as a matter of lubrication, and to seal the clearance space.

How is an excess of glycerine provided for ?

Any beyond what is needed to fill the clearance spaces passes through the delivery valves with the gas and drains through a trap to the bottom.

Are there any chemical and mechanical difficulties in the use of glycerine in this way ?

Nc, as carbonic acid and glycerine have no affinity for each other.

How are leaks of glycerine made good ?

In large machines by a belt-driven pump, and in small ones by a hand pump which can be operated every few hours.

Is some leakage of glycerine unavoidable ?

Yes, ard it must be replaced by a hand pump occasionally.

How is the gland made gas-tight ?

By means of two cupped leathers on the compressor rod.

When will some refrigerant escape ?

When a compressor is opened up for the inspection of valves, etc.

What is to be said about the joints ?

It is claimed that these can be made absolutely tight with leather or any other suitable material, except where there is a high temperature. Here the difficulty has been overcome by using joining rings turned out of a copper alloy. The tightness may be tested by brushing them over with soap and water.

What is one of the uses of the carbonic acid machine ?

The manufacture of liquid carbonic acid in breweries, lime burning plants, etc.

Is it inferior in efficiency to a compression ammonia machine ?

There is practically little difference if properly designed.

Why should liquid carbonic acid be tested ?

Because it may contain air, water, oil or grease, carbon disulphide, hydrocarbons, etc.

Is carbonic acid used from fermenting processes ?

The collection of carbonic acid on a commercial scale from fermentation of beer, spirits, vinegar and molasses has been a proved success for many years.

Is it reasonable in cost ?

The cost is only a few cents per pound, and the quantity required for a complete charge is very small, being only about a dollar per ton of refrigerating capacity.

How may breweries obtain carbonic acid in their own works ?

The collection of carbonic acid in a brewery may begin about twenty-four hours after the wort has been pitched, but in a distillery the attenuation is often so rapid that pumping may be commenced from four to six hours after the mash is run into the tuns ; in either case the process can be continued till the yeast head is first skimmed off, or till the fermented wort or mash is run out of the tun.

How should the apparatus for collection be arranged ?

The type of apparatus through which the gas is drawn from the tuns may be varied to suit each particular situation ; but as the gas immediately above the yeast head is the least mixed with air, it is necessary that the collector should be capable of being raised or lowered to suit the varying level of the infusion.

How is the carbonic acid purified ?

Purification is usually effected by passing the gas through a series of three sets of horizontal purifying vessels. In the first purifiers the gas is washed through water, which is slowly but continually changed. The next series of purifiers contain sulphuric acid, through which the gas percolates, and by which all volatile ethers are removed from the carbonic acid. Finally, the gas is again washed in a very weak solution of permanganate of potash.

How is it put in cylinders ?

In cases where it is intended to sell the collected carbonic acid it is usually necessary that it should be purified, and it must always be liquefied and bottled in suitable steel flasks. If, on the other hand, the gas is to be used in the brewery for carbonating purposes, separation of the gas from the other products of fermentation is unnecessary, and the gas may be conveniently stored in receivers at a pressure of about 200 pounds per square inch.

How much carbonic acid is shipped in a cylinder ?

About twenty pounds.

How is it stored in cylinders ?

The compression of the gas is effected by a set of pumps forming a stage compressor, the first pump also drawing the gas by suction from the fermenting tuns. After leaving each pump the gas is cooled to abstract the heat generated during compression.

How does the compressor compare in size with an ammonia compressor ?

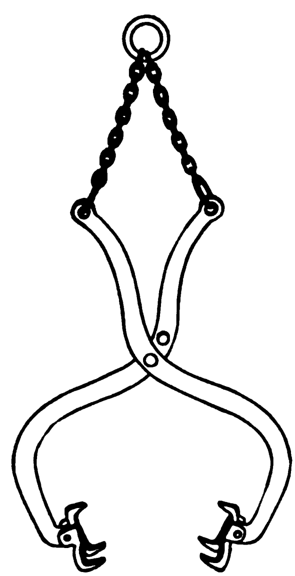
It would have to be 200 times as large to be of the same capacity.

How do the manufacturers of vacuum machines avoid such large compressors ?

By using some absorbent of the watery vapor, especially concentrated sulphuric acid.

What is the summing up of the vacuum process ?

The refrigeration is effected by evaporation, the air gaining access either under natural conditions or by artificial draught; or the evaporation is hastened by reducing the atmospheric pressure.



COMPRESSED AIR SYSTEM.

Who invented the first air machine?

Franz Windhausen, of Berlin.

When was the first machine brought out?

In 1889.

What is the characteristic feature of the compressed air system?

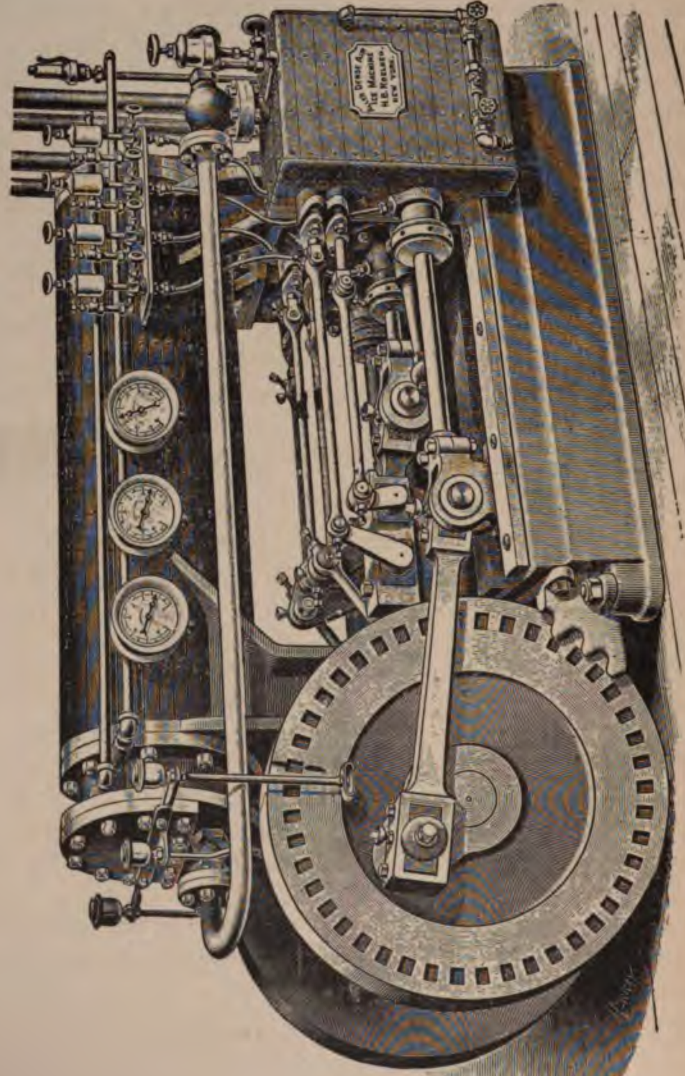
That the air is not condensed to a liquid.

Explain the operation of the Cold Air machine?

In the compression cylinder the air is compressed to a pressure of ten to fifteen atmospheres, and its temperature raised from 75 degrees to 500 or 600 degrees. This heat is conducted off by the compressed air being held in a coil surrounded by water, or in long pipes passing through the atmosphere as when used for rock drilling machinery. The heat may be reduced by conduction to 75 degrees, but the pressure is still, say, fifteen atmospheres. If this should be allowed to escape into the atmosphere a temperature of zero to 10 degrees Fahr., would be produced, part of the low temperature being due to the energy required to force itself into the air again against an atmospheric pressure of 14.7 pounds per square inch.

Why has the compressed air system been favored on shipboard?

It was an early development of the business, and in the days, too, when no supply of carbonic acid or ammonia could be had in ports over the world, as is the case nowadays.



Outside elevation of an Allen Dense Air Refrigerating Machine, as shown diagrammatically and in outline on pages 386 and 389.

What are the essential parts of a compressed air plant?

A prime motor, a compressor, a cooling coil of pipe with a water supply, an expander consisting of a cylinder, piston and valves, arranged like those of a steam engine, with cut off so that the cooled compressed air may be admitted during a portion of the stroke, and act expansively during the remainder, thereby compelling it to take up heat from the surrounding atmosphere.

On the return stroke this cooled air is expelled into the coils of the refrigerator, and then returned to the compressor.

What is, therefore, absolutely necessary to make use of the refrigerating power of the air?

The expansion cylinder must be well insulated to prevent the expanding air from taking up heat from the air surrounding the cylinder. The temperature thus drops, and the air will be able to take up the heat from the refrigerating coils.

What are the main objections to air machines, afloat?

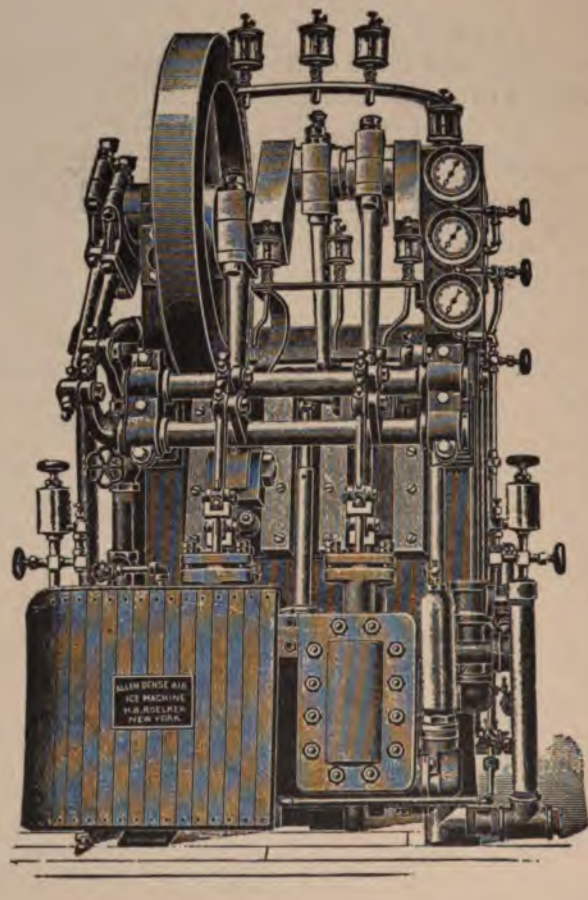
The large space required, the high cost, comparatively, of operation, and the amount of moisture in the air which interfered not only with the working of the machinery but also in the form of ice or snow is deposited over goods, otherwise the harmlessness of the refrigerant is greatly in its favor.

Describe the working of a Windhausen machine?

In the Windhausen machine, which was for a time largely used in marine service, the air, after being compressed in a cylinder has the heat of compression carried off by cooling water. It then expands in a cylinder, its temperature being reduced corresponding to the amount of work done ; it then escapes into the room to be cooled, cooling and ventilating the room at the same time.

What is the temperature in the conveying pipes?

About 60 degrees below zero.



Perspective view of the Marine Type of the Allen Dense Air Machine as shown in outline on pages 386 and 389.

How is the moisture a disadvantage in the air machine?

It freezes to ice, or if in a state of vapor forms snow, and not only do the ice and snow clog the valves, but the vapor in changing to a liquid state gives its latent heat of vaporization to the air.

How does the Allen Dense Air Machine overcome the objections to an air machine?

The air is kept in the machine at 60 pounds gauge pressure and used over and over.

What are the conditions of operation?

The machine is constructed to stand 60 pounds pressure in the conveying and refrigerating pipes and 210 in the compressor. Great care must be taken that the trap, valves or pipes are not clogged by frozen oil or snow, and the best quality of mineral lubricating oil must be used from which the paraffine has been extracted.

What special advantages does a machine of this type possess?

The refrigerant is everywhere available and a yacht or vessel could go anywhere without possibility of running out of a supply, which might happen if ammonia or carbon dioxide was used.

The refrigerant costs nothing.

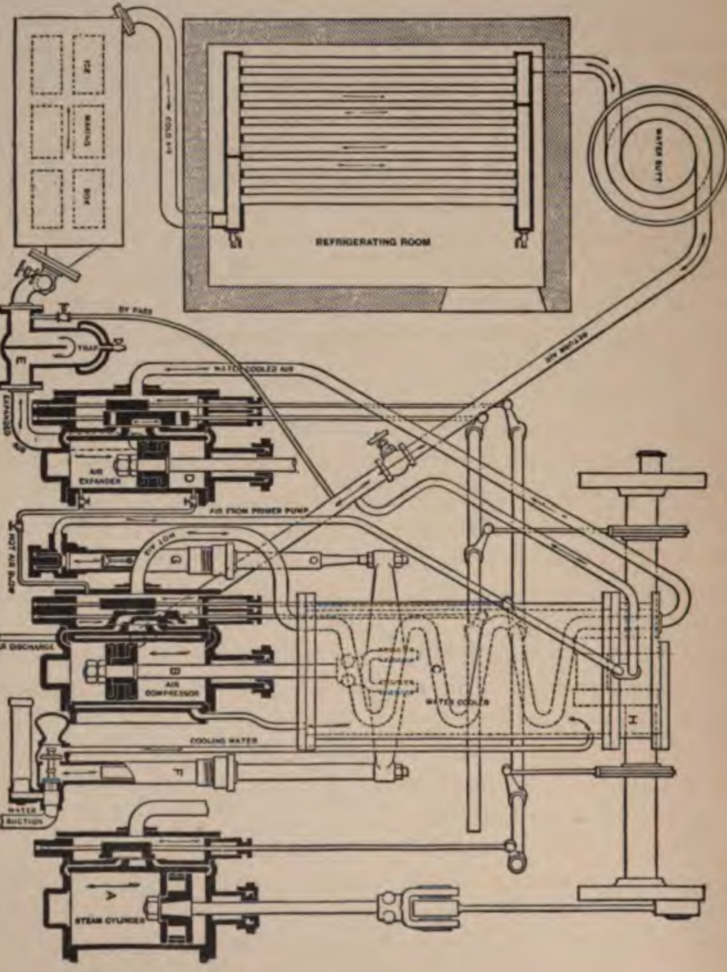
Slight leaks can do no harm.

Copper can be used in coils, which is an advantage in salt water.

The machine can be put in the engine room where its operation is under the eye of the chief engineer.

Less space and power is required because the air is used over and over.

In case of accident the escape of the air would not be dangerous like ammonia, and probably would do little if any harm.



Diagrammatic plan view of an Allen Dense Air Refrigerating plant, showing all the essential features of the machine. The reference letters are explained on pages 387 and 388.

What are the important parts of the Allen Dense-Air Machine ?

A. The steam cylinder which furnishes the power to its crankshaft, to which the air compressor and the expander are linked. The letters refer to the opposite diagram.

B. The air compressor cylinder which compresses the air to about three times the entering pressure. As this causes the air to heat, the cylinder is surrounded by a water jacket to make lubrication practicable. The compressing cylinder is constructed with slide valves, instead of the usual conical lift valves, in order to move more quickly and noiselessly.

C. A copper coil in a bath of water ; the compressed hot air in passing through it cools to the temperature of the water.

The return air-cooler which still further reduces the temperature of the air.

D. The expansion cylinder, to which the cooled compressed air is admitted until it fills one-third of the volume of the cylinder. The air supply is then cut off, and as the piston makes its full stroke to the end of the cylinder the air expands until the tension is about normal, and the expansion cools the air about as much as the compression heated it. It is constructed like a usual steam-engine cylinder, with slide-valve and cut-off valve. It must cut off the pressure at such a point that the expanded air at the end of the stroke of the piston is very nearly of the same pressure as the air contained in the system of pipes. If it were of much higher pressure it would, at exhausting, warm up again, by exerting its remaining power in producing velocities and frictions inside of the apparatus.

The air, therefore, leaves this cylinder at a very low temperature and is discharged into a well-insulated pipe which conveys it to the point of use ; there the pipe is exposed and the cooling is effected, the air returning to be used over. The expander helps the steam cylinder and the air compressor takes the power.

E. A trap placed just after the expander which intercepts any oil and snow; the trap is provided with a heating pipe and

the contents of the trap should be drawn off every few hours. The machine is so arranged that at the same time any frozen deposits in the expander cylinder can be thawed and blown into the trap.

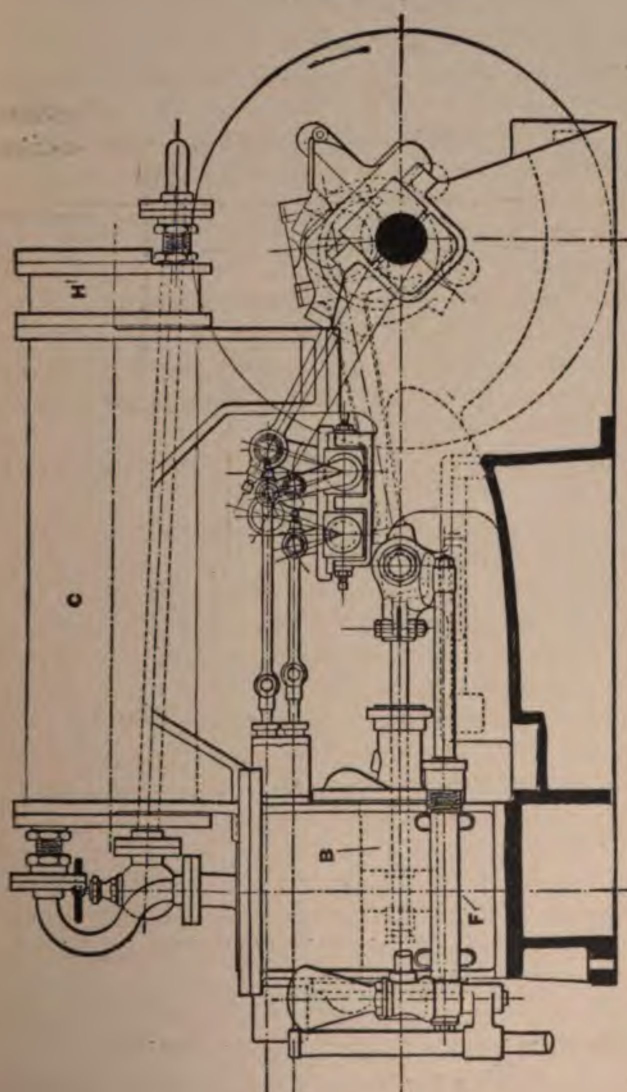
F. Is the water-pump which circulates water around the copper coil C, and through a water-jacket which surrounds the working cylinder of the air-compressor B, in order to prevent the heat from injuring the packings.

G. Is a small air-compressing pump which takes air from the atmosphere and pushes it into the machine and pipe system. This charges the system with the requisite air-pressure when the machine starts to work, and maintains the pressure against leakages occurring at the stuffing boxes and joints. This air, of course, contains the usual atmospheric moisture, and to expel this, the outlet pipe from this pump passes the air through the trap H.

H. A small trap where the air is cooled by being forced into very close contact with the cold head of the reservoir for coil C. This cooling under pressure and contact with moist surfaces deposits out of the air about 80 or 85 per cent. of the contained moisture, which is then drained off by pet-cocks, leaving pure air for the refrigerating work. This is of great importance, as the large amounts of latent heat in the water vapor and latent cold in frozen water would produce very serious losses in the result of the machine if the air contained water, which would be subject to the heating and freezing processes which occur in the machine. Surplus air is blown off by a small safety valve.

What special care does the Allen machine require ?

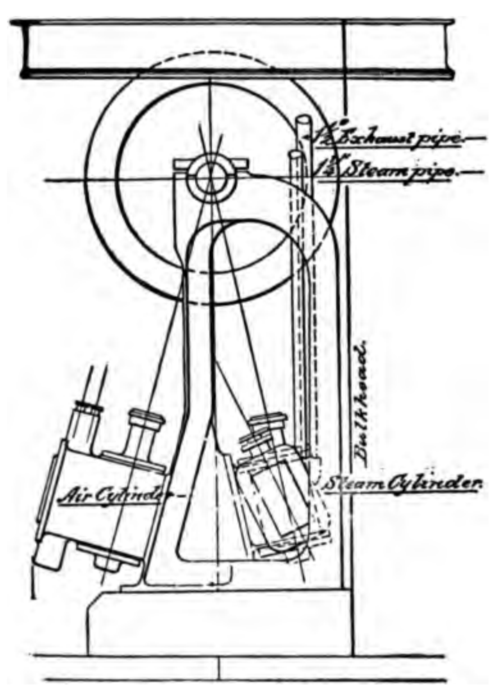
Very little besides looking after the traps for oil and snow. They should be cleaned or blown out as may be required. A good water supply is necessary as is the case with all makes of refrigerating machinery.



Side elevation of the Allen Dense Air Refrigerating Machine.

How are the stuffing boxes constructed ?

The air stuffing boxes contain first a few rings of soft metal packing rings, then a hollow oiling ring, then outer layers of fibrous packing. The oiling ring is kept full of oil by a sight feed pressure lubricator which is connected by a pipe to the stuffing box.



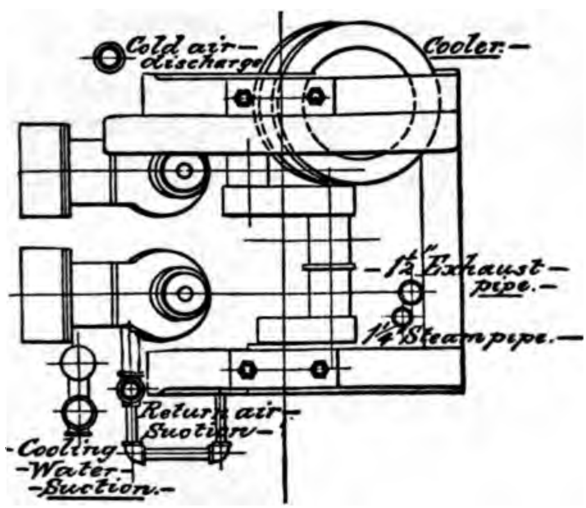
End elevation of the Allen Marine Type Air Machine as installed between decks on shipboard.

What other advantages has it over older air machines ?

It is very much smaller and only requires half the steam.

What is the method of operation ?

The air is first compressed, during which process heat is generated ; this heat is abstracted in an apparatus similar to the condenser. The refrigeration is produced by allowing the compressed air to expand while doing work ; the re-expanded air is reduced in temperature and is circulated in coils.



Plan view of the Allen Dense Air Marine Type Refrigerating Machine.

What is the principle of thermo-dynamics involved in this process ?

When a gas is allowed to expand while doing work, the amount of heat given out by the gas is equal in mechanical energy to the work done.

What action has the air still to take ?

It passes into the expanding cylinder, and entering at, say, 150 pounds pressure, aids the steam cylinder in its work, and passes into the cooling coils at 40 to 70 degrees below zero.

What apparatus does this involve ?

Only the priming pump, which compresses the air at starting, and the two traps.

What minor additions to the plant are necessary ?

Traps for the separation of oil and snow from the cold air, and for taking moisture out of the fresh air.

How are the compression and expansion cylinders packed in the Allen machine ?

By cup leathers held in position by iron follower rings.

How are the packing leathers treated before use ?

They are soaked in castor oil

If compressed air is expanded without doing work, what will be the effect upon the temperature ?

If the air should be expanded into a vacuum there would be no drop in temperature but the high velocity of the air, if passing through an orifice while expanding, would by friction heat up considerably. If the air is allowed to expand freely into the atmosphere, there would be a certain amount of work done in displacing the atmospheric air, and the temperature would drop equivalent to the work done.

SULPHUROUS ACID SYSTEM.

Describe the Sulphurous Acid Machine ?

This type of machine has been largely developed by Raoul Pictet. It has the advantage of requiring only comparatively low pressures, and sulphurous acid is a good lubricating medium. This fact simplifies the mechanical details of the machine and it is in use to some extent on the continent of Europe for small plants where the service of a skilled engineer is not practicable.

The main objection to the use of this refrigerating agent is the great tendency of sulphurous acid to take up moisture and change to sulphuric acid, consequently great precautions must be taken to avoid leaky joints.

How does the Pictet compressor differ from the ammonia one ?

Only very slightly in construction.

What are the advantages of sulphur dioxide or sulphurous acid ?

It being an oily liquid no lubrication is required in the compressor, and it greatly simplifies the machine to have no oil separators or rectifiers.

What advantage does sulphurous acid have over ammonia ?

It requires only from one-half to two-thirds the pressure ; as it has no action on copper or brass these metals may be used for piping, the former being very desirable for that purpose, the only objection being the expense.

What is Pictet's Liquid ?

A refrigerating agent made of a mixture of carbonic acid and sulphurous acid, the percentage of the former being very small.

What is Sulphurous Acid or Sulphur Dioxide ?

A colorless gas having a very strong odor of burning sulphur. It neither supports respiration nor combustion, and is about 2¼ times heavier than air.

It liquefies under atmospheric pressure at 14 degrees Fahr., and assumes a solid form about - 168 degrees Fahr.

How much greater compressor capacity do sulphurous acid machines require than ammonia machines ?

Nearly three times as much.

Does sulphurous acid, when pure, have any chemical action on the parts of the machine ?

Like ammonia, and carbon dioxide, it exerts no chemical action when sufficiently pure.

How do the sulphur dioxide machines differ from others of the compression type ?

By relatively large cylinder volumes and low pressures.

Why do they appear more simple than the ammonia compression machines ?

Owing to the omission of the oil separators and rectification apparatus.

Does the sulphurous acid compressor become heated ?

Even more than the ammonia cylinder.

How is the heat carried off ?

By a water jacket, as in the ammonia type.

Is any oil used in the sulphurous acid machine ?

Sometimes when a stuffing box heats, the engineer may use a little solid fat, but care must be taken not to let it solidify and obstruct the suction valves.

THE ETHER SYSTEM.

How is sulphuric ether produced ?

By the action of sulphuric acid on vinous alcohol.

What is methylic ether ?

It is produced by the action of sulphuric acid on ligneous or wood alcohol.

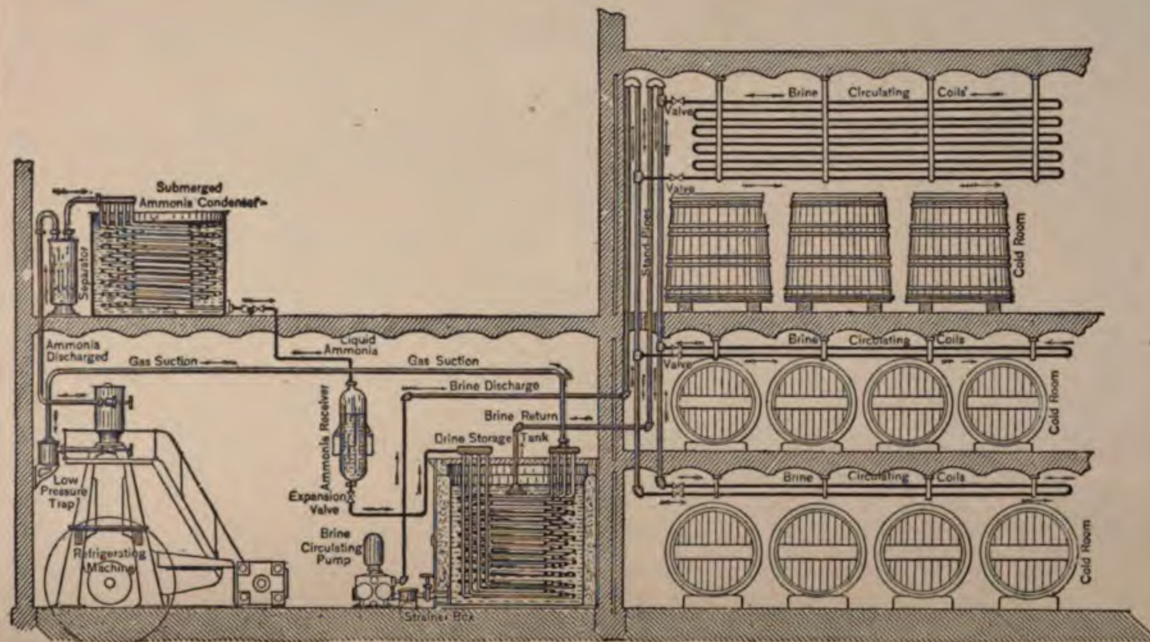
These two ethers, sulphuric and methylic, are substantially the same; their method of formation by the agency of sulphuric acid is as noted in the answers.

Describe the Ether Machine ?

This type of machine has never come into extensive use owing to the relatively large compressor necessary, but more especially to the inflammability of ether and the great liability to explosion. The great advantage of ether is that it requires only a low pressure in the condenser, which is of no little importance in warm climates, and which has led to its use by the British military authorities in several campaigns in Africa. The low pressure is also favorable for the maintenance of tight joints, and the simplicity of the working parts. Another important fact in connection with military operations is that as ether is in a liquid state under ordinary conditions of temperature and pressure, it can be drawn out of the plant at any time and stored in drums, thus making this type of machine easily and quickly portable.

How does the Compressor compare with other systems ?

The compressor required is very much larger than in an ammonia machine of like capacity, and its generally massive construction, and larger consumption of coal and water, added to the great fire risk, have seriously handicapped the ether machine for ordinary commercial use.



A brine circulating system in brewery cellars.

CIRCULATION SYSTEMS.

Where does the ammonia go after leaving the liquid receiver ?

It goes to the refrigerator or ice tank after first passing through the expansion valve.

What is the expansion valve ?

A special valve which is placed at the beginning of the refrigerator coils; its peculiar advantage is that it is capable of very fine adjustment. (See pp. 127 to 130, 176, 180.)

How wide is the expansion valve usually opened ?

From 1-100th to 1-8th of an inch.

How does this affect the pressure ?

It reduces it from 150 to, say, 15 pounds.

What is the action of the expansion valve ?

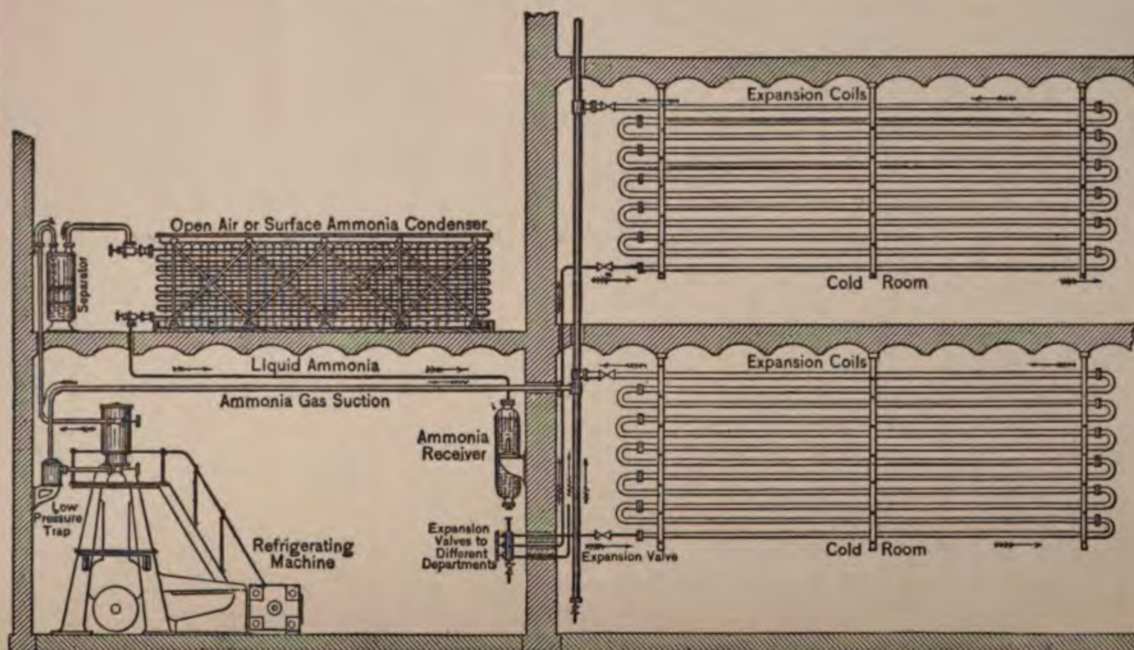
The ammonia being allowed to pass through in a very small stream only, is released from pressure, therefore it can expand into the gaseous condition.

How is the work of the expansion valve utilized ?

The ammonia gas may be expanded in a room which is to be cooled, in which case it is called the direct expansion system, or the gas may be expanded in a bath of salt brine and the latter circulated through the room to be cooled; this is called the indirect expansion or brine system.

How are the expansion coils fed ?

From the bottom, if using liquid ammonia; if working with the wet vapor of ammonia, from the top.



Eclipse direct expansion system. The pipes here are shown on the sides to better illustrate the system. In practice they may be placed either on the sides or ceiling as the circumstances may render necessary.

Describe the direct expansion system.

With this system the ammonia pipes instead of being placed in a tank full of brine, are placed in the rooms and cool the air direct without the intermediation of brine. It can be readily seen that where the ammonia pipes are placed in the rooms the efficiency must be greater, as the various losses which arise by transmitting the cold first to the brine and from the brine to the air, are done away with. On this account, the expansion pipe system is much more in general use than the brine pipe system, although the latter system has many advantages. When the expansion pipes were first used for cooling the rooms direct, the general public had an aversion to this system on account of the possible danger that through leaky joints or burst pipes, the ammonia would be discharged in the rooms and spoil the goods. This prejudice, however, has died out.

What is meant by the "flooded" system?

In a flooded system the liquid ammonia is fed into a trap from which it enters the bottom of the coil passing upward and through the same and discharged back into the trap it started from, where the gas that has been formed is separated from the liquid that remains, the gas going through the top of the trap to the compressor, while the liquid is thrown down in the trap, where it mingles with the fresh liquid being fed into it, and the cycle is repeated.

What should be the sound of the ammonia in passing through the expansion valve?

It should be continuous and sonorous, showing that it is not a mixture of gas and liquid. A rattling noise shows that vapor as well as liquid ammonia is passing.

What is the usual size of brine pipe in storage rooms?

Two-inch is a favorite size because there is less friction than in smaller sizes.

How much more pipe does the ordinary expansion system require than the flooded system ?

An expansion system, or one where the ammonia leaves the coil slightly superheated, requires about one-third more pipe surface than a wet compression system, which is a system where the ammonia leaves the coils containing sufficient entrained liquid to maintain a wet compression condition in the compressor.

There is usually from 300 to 350 feet of 1 1/4-inch pipe, or its equivalent, per ton in freezing tanks. The same work may be done with from two-thirds to one-half of this amount if it is properly arranged.

Does the liquid ammonia evaporate immediately after passing the expansion valve ?

The idea is a mistaken one, that liquid anhydrous ammonia at once "expands" or "flashes" into a gas upon its release through an expansion valve, into coils of any description regardless of the temperature at which it enters the coil or that of the coil itself, and that this gas, while passing through the coil, abstracts the heat from the coil, thence from the surrounding elements, such as air, water, brine, or other bodies.

How can this be demonstrated ?

The simple experiment of evaporating a small quantity of liquid anhydrous ammonia in a test bottle, where the conditions as to pressure are even more favorable for evaporation than those existing in refrigerating plants, convinces us that anhydrous ammonia, can and does exist in its liquid state after having passed the "expansion valve" of the system. The cooling effect becomes apparent on that portion of the surface of the bottle only which is in direct contact with the evaporating [illegible] hich is merely touched by expanding

Will this rapid ebullition in the test bottle continue long?

It does not, owing to a quick envelopment of the outer surface of the bottle (up to the liquid line) with a coating of frost, which prevents the penetration of heat.

What practical lesson can we learn from this experiment?

The same process which is so plainly apparent in this simple experiment with a test bottle takes place in every freezing coil. Only that portion of its inner surfaces which is covered by, or continuously sprayed with, liquid ammonia, will be available for the really efficient abstraction of heat.

What effect has the formation of frost on the pipe?

As soon as the abstraction, due to the evaporating process, has proceeded to the point where the temperature of the piping has been reduced to that of the boiling point of ammonia under the prevailing pressure, and as soon as the formation of frost around the piping retards the admission of heat, the previous rapid evaporation gives place to a slow or retarded one. The continued supply of the refrigerant will now flow tranquilly over the chilled surfaces until it reaches a place in its travel where the temperature of its surroundings is higher than its boiling point, at which time the evaporation is resumed.

With this gradual progress in cooling, the coil, or system of coils, becomes gradually "flooded" even when, by virtue of the most perfect and approved "expansion valves," the admission of the refrigerant is so regulated as to make the quantity of the liquid supply exactly correspond in weight to that of the escaping vapor; and further, providing that the entire cooling surface of the coil is brought into actual service.

What two facts does it therefore make necessary to bear in mind?

First: That the full cooling or heat abstracting ability of the provided coil surface can only be obtained when such surface is covered, or continuously sprayed with the refrigerating liquid.

Second: That the vapor liberated from the refrigerant, and having the same temperature as the former, produces only an inconsiderable cooling effect.

What two effects will be produced by the introduction of the refrigerant into a coil ?

The generation of ammonia gas or vapor will effect a continuous spraying of the inner surface of the coil, near the point of entrance. These gases, when passing through the coils from bottom to top, assuming them to be of the vertical type, will also create a disturbance in the liquid which obstructs their travel to the outlet, and will thereby contribute to an intimate contact of the fluid with the surface of the coil.

What does this show in relation to the best method of admitting the ammonia into the expansion coils ?

That the maximum efficiency of the cooling surface of a vertical coil can never be obtained by entering the refrigerant at the top, as it only would come in contact with the lower part of the inner circumference of the piping, while the upper and larger part of the surface would merely become efficient through the conduction of heat around the metal of the piping. When, however, the liquid ammonia is admitted to the lower end of the coils of the vertical type a marked difference is produced.

What is the effective work produced by the expansion of one pound ammonia in the refrigerating coils ?

Assuming that we operate a combination of freezing coils under a gauge pressure of 15.67 lbs. and a corresponding temperature of zero Fahr., and further assume that the liquid supply from the receiver enters the feed valves to this set of coils at a temperature of 80 degrees Fahr., it follows that with the sudden release from pressure of this liquid, 80 x 1.23 equals 98.4 heat units are liberated which causes an instantaneous evaporation or expansion of a portion of this supplied liquid.

The conversion of one pound of liquid ammonia at 0 degrees Fahr., and its corresponding pressure of 15.67 lbs. into vapor of a like degree of temperature, requires the expenditure of 555.5 B. T. U. When admitting the liquid supply at a temperature of 80 degrees Fahr., nearly 100 B. T. U. become liberated from each pound of the admitted fluid, which causes an immediate evaporation of 18% of its quantity. The temperature of the remaining 82% is thereby reduced to 0 degree Fahr., leaving only this quantity available for effective refrigeration for the reason that the 18% of liquid which was converted into gas at 0 degree Fahr., can absorb but 2.25 B. T. U. from the surface of the coils, until it escapes with a final temperature of even 32 degrees Fahr.

The evaporation of an equal weight of liquid by heat exchange with the coil, would have absorbed nearly 100 B. T. U.

This fact, combined with other obvious causes, is one of the principal reasons why prevailing high condenser pressure, and corresponding high temperature of liquid supply, depreciate to such a marked degree the efficiency of an ice making or refrigerating plant.

How can we avoid such loss in efficiency?

By careful consideration of the placing of the ammonia receiver which should be in a cool place, also any piping from the ammonia condenser to the receiver should be well insulated if passing through warm rooms.

What should be the aim for satisfactory working?

We should endeavor to have the entire available heat absorbing surface continuously covered or sprayed with the liquid refrigerant, the object being not to exchange the small amount of the sensible heat of the escaping gases, but the employment of the greater amount of the heat absorbing power due to the evaporation of the liquid itself, as it is the latent heat of its evaporation which produces the desired results.

What is the liquid trap ?

A trap placed between the expansion valve and the refrigeration coils. As vaporization takes place within it, it is designed to catch oil or other foreign matters, and prevent their passing into the pipe.

How low a temperature can be obtained by the use of direct expansion ?

A temperature as low as –28 degrees can be had, but there is little use for a temperature below zero for storage purposes except for fish freezing, and even then their storage afterward requires no lower temperature than 18 degrees Fahr.

What is an important advantage in the direct expansion system ?

The temperature in the expansion coils does not need to be so low as would be necessary to cool brine, hence, a higher suction pressure can be carried.

What kind of refrigeration is now most generally favored ?

The direct expansion because it is the most economical in construction as well as operation.

How much greater efficiency does the direct system show over the indirect ?

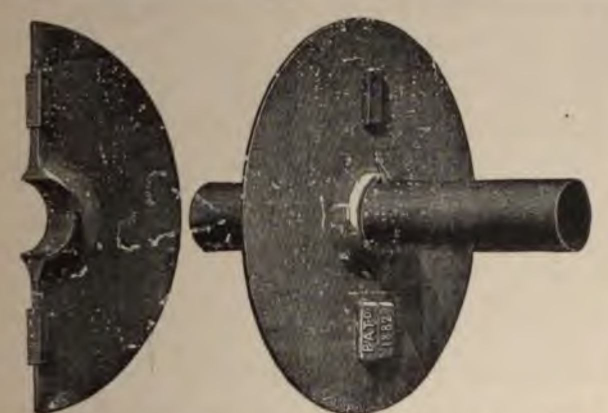
Perhaps as much as twenty per cent.

Which is the least complicated to operate ?

The direct expansion system is much simpler to operate than the brine because of the auxiliary apparatus that is necessary in the latter system. In the direct expansion system all these intermediate agencies are dispensed with, and the refrigeration is produced at the place where it is utilized. Neither is as much power necessary to produce the same amount of refrigerating work as is required in the brine system, to say nothing of the extra cost for repairs and maintenance.

When is the heat absorbed ?

When the expansion coils are placed directly in the rooms to be cooled. This method makes it possible to use the entire capacity of the ammonia compressor. Here, too, the liquid ammonia is utilized to the best advantage. Each pound of ammonia that enters the system has just so much refrigerating energy stored up, and will absorb a much larger quantity of heat than it would if first expanded in the coils of a brine tank. That is, the expansion surface is larger than that of the brine system and the liquid ammonia will be expanded at a much higher temperature and pressure, which results in a gas of a higher density and the ammonia compressor will circulate a greater weight of ammonia gas per minute.



Radiating disks showing the method of attachment to the freezing coils. These disks are placed upon the pipes to increase the heat conducting surface.

What is a disadvantage of both systems ?

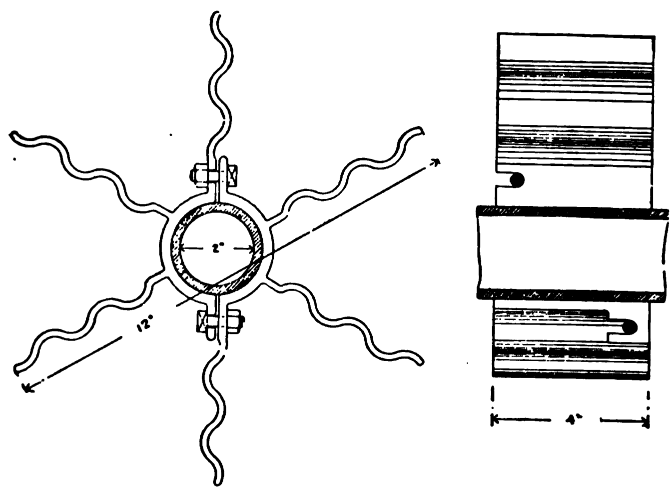
That ice forms on the outside of the pipes, which, increasing in thickness from day to day, prevents the cold from being transmitted to the air, as ice and snow are not good conductors.

Are certain methods of cleaning the pipes from frost objectionable ?

Hammers and chisels are sometimes employed but are liable to injure the coils and should never be used around the valves.

How is ice best removed from coils ?

With calcium brine; if removed daily it is loose enough to come off easily.



Radiating strips attached to freezing coils. These are sometimes used in place of the disks illustrated on page 405.

What are disks and how are they used ?

They are thin circular or oval pieces of cast iron clamped at intervals of about a foot to cooling pipes to increase the effective cooling surface. They are cast in halves so as to be easily placed on the pipe.

Are they generally used ?

Many engineers consider that the cost of the disks would render much more effective service if expended for extra piping.

What is the objection to placing refrigerating pipes, either ammonia or brine, in the rooms to be cooled ?

It is difficult even by the most approved distribution of the coils and arrangement of stored goods to secure an even temperature in all parts of the room; then, too, condensation on the pipes causes dripping and consequent damp walls, floors, etc.

Having already described the direct expansion system, now describe the brine system.

The liquid ammonia is passed through a regulating valve into hermetically sealed pipes where the ammonia is given time to absorb the heat it requires for its evaporation. Next, these hermetically sealed pipes are placed in a tank which is filled with a solution of salt and water called brine, of such density as to be able to hold a low temperature without freezing. The ammonia pipes submerged in this brine, abstract the heat from the brine and cool it. The brine after being cooled down to a low temperature, is pumped through pipes hung up in the different rooms where cooling is required. Here the brine absorbs heat by cooling the air and then returns at a higher temperature to the refrigerator where in turn the ammonia coils absorb the heat and cool the brine which is again pumped through the pipes in the room, and so on continuously. This system of cooling rooms is very successful, though the first cost, and the cost of working, is higher than the cooling by expansion pipes. The brine pipe system, however, has many advantages inasmuch as it can be easily regulated.

What special advantage has the brine system over the direct expansion ?

One of the advantages claimed for the brine system is the ability to store refrigerating energy in the brine tank, which may be drawn upon during the night, thus rendering the continued operation of the compressor unnecessary.

What is brine and why is it used in refrigeration ?

It is a non-congealable liquid used for absorbing the effect of an expanding gas and applying it to the work to be done.

How is the brine made ?

For a long time common salt has been used but it is now being largely displaced by chloride of calcium.

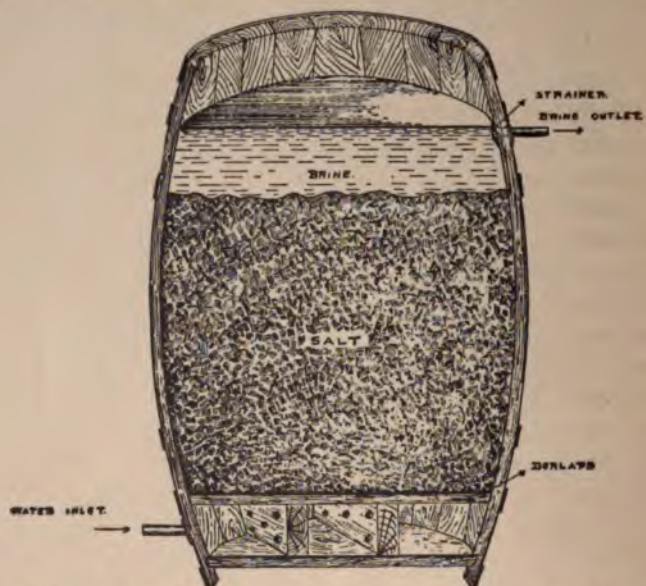


Illustration of method of making salt brine, as explained on page 409.

Why has calcium not taken the place of salt more rapidly ?

Its first cost has been greater; it is more difficult to prepare and handle, and it is not everywhere as easily obtained as salt.

What do makers claim for calcium chloride ?

That it is a better medium of refrigeration, and that it is not so destructive to the pipes as sodium chloride.

How do these two salts compare in use ?

Their action on the interior of a pipe will probably not vary much, but wherever the brine has access to the exterior of the pipe as from a leaky joint, the corrosion and deterioration from sodium brine is much greater than from calcium brine.

What is the reason for this ?

The latter will hold its moisture much longer, so that the pipes are not likely to become dry; it is the alternate drying that rusts and pits the pipe.

Are chloride of calcium and chloride of sodium harmful ?

No, the only disagreeable feature is the property of making everything damp with which they come in contact.

Do these two salts contain impurities ?

The objectionable features of chloride of sodium probably come from its impurities. Chloride of calcium also contains impurities at times.

How do salt and calcium compare in price ?

Salt is about half the price of calcium.

What should be guarded against in buying salt for ice making ?

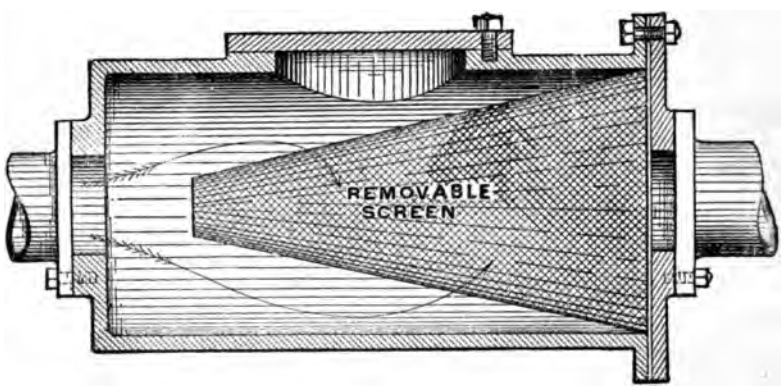
That it does not contain too large a percentage of insoluble matter.

How is salt brine solution prepared ?

One of the best methods consists in allowing water to percolate through a body of salt, thus, take a large water-tight barrel or cask, as shown in cut on page 408, and fit a false bottom or wooden grating six or eight inches above the bottom—this can be made of strips of wood about an inch square, and placed not over one-half inch apart. This false bottom should be supported by two strips of board each six inches in width, placed on edge

and nailed to the bottom. These boards should have several holes bored to permit a free passage of water. The water inlet should be below the false bottom.

A single thickness of burlaps should be stretched across the top of the false bottom and tacked to the sides of barrel. The outlet pipe for the brine should be four or five inches below the top of the barrel, and the water supplied at the bottom from a convenient hose or faucet. The supply pipe should be of about 1¼ inch diameter, and the outlet pipe about 1½ inch inside diameter. If it is necessary to make brine faster than can be accomplished with one barrel, fit up two or more extra barrels.



Brine strainer. This apparatus when placed in the brine circuit will intercept any scale or dirt, which will accumulate in the shell, and which may be removed through the hand hole.

To make brine—fill the barrel above the false bottom with salt and turn on the water. The salt will dissolve rapidly, and more must be shoveled in on top. The barrel must be kept full of salt, or the brine will not be of full strength. **No stirring is necessary.** Keep skimming off all waste matter rising to the top. The brine outlet should be provided with a strainer of some kind, somewhat as shown in the above figure, to prevent chips, etc., from running out with the brine.

This mixer as it is called, should form a permanent part of the plant, and a connection be made between the return brine pipe from the refrigerating system and the barrel so that the brine may be passed through the mixer from time to time as may be found necessary to maintain the desired strength.

How is salt brine made in large quantities ?

It is well to have a spare tank located above the regular brine tank when large quantities are wanted. One can make the brine in this tank and allow it to flow by gravity into the regular tank below. If the bulk salt is dumped directly into the tank it might form a pile on the bottom and cause trouble. Having the extra tank will make some extra labor, but it obviates trouble in some other part of the system. By adding salt a little at a time, and using the salinometer, the operator can gradually bring the density of the brine to the right point with very little labor. (See page 38.)

What strength of brine is required ?

One to two pounds of salt per gallon, more or less, as may be needed for the temperature required in the tank.

Why should the strength be carefully regulated ?

Not only might it cause deposition of the salt on the pipes and consequent clogging, but the specific heat grows smaller as the concentration of the brine increases.

How is the strength of the solution governed ?

It is regulated by the lowest temperature it is liable to reach, leaving a sufficient margin between this point and the actual freezing point of the solution, to provide for any unusual drop in temperature.

What solutions are used in practice ?

From 40 to 90 degrees, salometer.

How may the brine be tested?

The strength of the brine solution is tested by a gauge called a salometer. This consists of a weighted glass tube and bulb which is graduated from 0 to 100. When floated in water the zero mark stands at the water level, but when placed in a saturated solution of salt brine, the stem sinks to the 100 mark. Intermediate points on the scale indicate different degrees of saturation.

TABLE—CHLORIDE OF SODIUM (SALT) BRINE.

DEGREES ON SALOMETER.	POUNDS SALT PER GALLON.	FREEZING POINT DEGREES FAHR.
0	0	32
5	0.105	30.3
10	0.212	28.6
15	0.321	26.9
20	0.433	25.2
25	0.548	23.6
30	0.664	22
35	0.78	20.4
40	0.897	18.7
45	1.019	17.1
50	1.142	15.5
55	1.265	13.9
60	1.389	12.2
65	1.522	10.7
70	1.656	9.2
75	1.791	7.7
80	1.928	6.1
85	2.067	4.6
90	2.207	3.1
95	2.347	1.6
100	2.488	0

A similar table for calcium solution can be found on page 421.

How is the brine system carried on?

The ammonia expansion coils are placed in a tank of salt brine which is cooled down to a desired temperature, and then by means of pumps the brine is forced through the piping in the rooms to be cooled.

Is salt brine liable to produce incrustation ?

No matter what grade of salt is used, it is bound to precipitate more or less and to coat the pipes.

An instance may be cited where salt brine precipitated a sediment of salt crystals upon the coils of an ice tank ½ inch thick. These salt crystals solidified and became as hard as rock and could not be dissolved, in fact could barely be broken off the pipes with a hammer.

How is the density of brine sometimes carelessly allowed to run down ?

It is natural for an engineer to run water into the brine tanks when he sees the brine getting low, but he does not, in every case, think to add a little common salt to keep the density of the brine at the right point. If this is neglected it will be impossible to reduce the temperature of the brine low enough to give the desired results in the cold storage rooms. In many cases the fault is improperly laid to the ammonia compressor, the absorber, the condensers, the expansion coils not being large enough, shortage of ammonia in the system, oil in the system, etc., when it is the brine that is too weak to produce the desired temperature.

Does the strength of the brine need close attention ?

The brine cannot be watched too closely, for it will cause trouble and annoyance if not kept at the right density. There is considerable loss of brine from evaporation and leakage depending upon the location of the brine tanks, and the tightness of the stuffing-boxes on the pump rods. Such losses as these are serious at times, and particularly where the engineer omits to test the density of the brine.

If brine gets too weak it will freeze on the pipes of the expansion coil, thus forming an insulation which obstructs the transfer of heat from the brine to the ammonia within the expansion coil, and the machine will not do its full work.

Is it necessary to carefully watch the expansion coils in the brine tank?

The expansion coils should be kept covered with brine at all times. Exposing a part of them alternately to the brine and air will cause oxidation which will corrode the pipes very rapidly and it will only be a matter of a short time before leaks will appear in the piping.

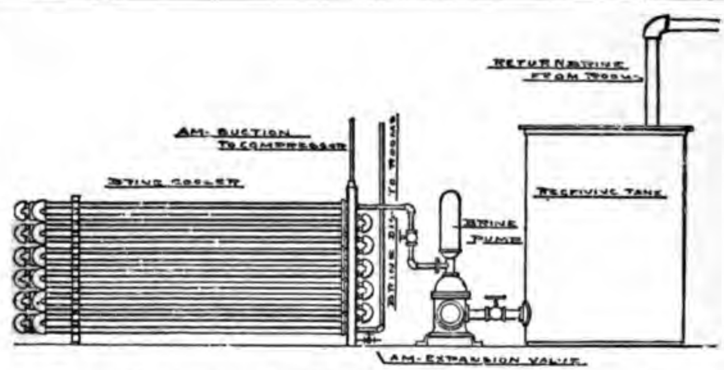


Diagram showing connection of brine pump to double pipe brine cooler. The construction of the double pipe cooler is the same as a double pipe ammonia condenser. The brine is fed through the inner pipe while the outer pipe forms the evaporating coils.

The exposure of the expansion coils will also reduce the efficiency of the system, as the exposed pipes would take up heat from the surrounding atmosphere instead of from the brine. The brine acts as a heat carrying conductor between the cold storage rooms or ice cans and the expansion coils, thus in the case of a cold storage plant the service of the exposed pipes is lost entirely. In the case of an ice tank but little heat would be conducted from the cans to the exposed pipes as air is a poor conductor of heat.

After the brine has been reduced in temperature to the desired degree it is impossible to reduce it any lower at that density.

Is it desirable to keep the brine in the tank in circulation ?

If an agitator of some kind is used, all portions of it will be brought into contact with the expansion coil, and will part with the heat more readily. The whole mass of liquid will be cooled more quickly, allowing more cooling work to be accomplished in a given time than would otherwise be possible if the brine were allowed to lie dormant in some parts of the tank.

Is it necessary to insulate the brine tank ?

In many cases the brine tank is insulated on the sides but no attention is paid to the bottom. A brick or stone foundation is a good conductor of heat and the condition is even worse if the tank is allowed to rest on the ground. In all cases heat is conducted downward about as easily as it will rise into the atmosphere. It is better to pay for proper insulation at the start than to be continually taking it out of the coal pile. A well-fitting cover should also be placed on top of the tank.

What detail in a brine tank should not be neglected ?

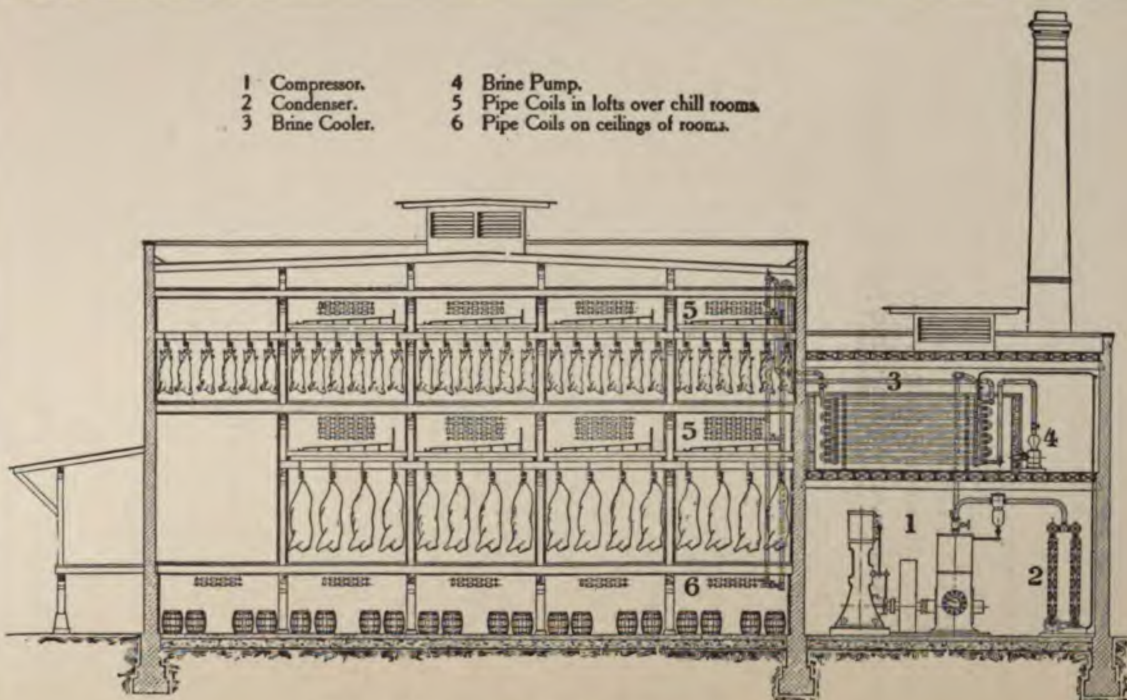
The covering of the top of the side walls.

How should brine tank connections be arranged ?

The pump suction should be several inches above the bottom so as not to become clogged with sediment; a removable strainer should be provided.

Does the arrangement of piping differ in the two systems ?

The arrangement of piping for a brine system is about the same as for a direct expansion system. In some plants the piping is placed on the ceiling, while in others it is run along the side walls of the cold storage rooms, as may be most convenient. In every case the piping is placed so that it will be out of the way and at the same time be within easy reach in case of repairs.



Brine circulating system of refrigeration in packing house.

What machinery is required for a brine circulation system?

The machinery required for the operation of a brine system is practically the same as that required for the direct expansion system with the addition of a pump to circulate the brine. The pump is connected and operated in the same way that pumps are installed for pumping liquids of any kind. Some engineers prefer to place the suction pipe of the pump so that the end will reach very near to the bottom of the tank in order that the coldest brine in the tank may be circulated through the piping in the cold storage rooms. The return pipe from the cooling coils is allowed to dicharge just below the surface of the brine in the tank. The suction and discharge pipes are usually placed at opposite sides of the tank, so that the comparatively warm brine will not be again circulated through the cooling coils before it has been reduced in temperature.

How rapid should be the brine circulation?

Not over 60 feet per minute.

Is more piping required for brine circulation?

Brine circulation requires from 50 to 100 per cent. more pipe surface than direct expansion.

What is a general rule for direct expansion piping?

One running foot of two inch pipe will take care of forty feet of space if it is to be maintained at 32 degrees Fahr.

How can the estimate be made in another way?

On a still more liberal basis it is frequently assumed that one ton of refrigerating capacity will take care of 4500 cubic feet of cold storage space from 32 to 35 degrees Fahr., and that from 200 to 250 feet of 1¼ inch pipe should be used for that purpose.

What arrangement of piping is preferable?

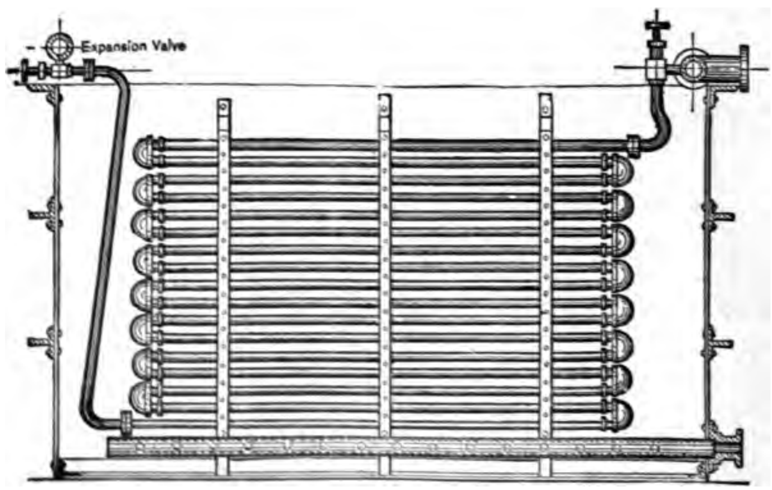
On the walls rather than the ceiling.

How did the brine circulation system come to be generally adopted in the early history of refrigeration ?

For fear of ammonia leaks and consequent damage to goods.

What is the proper temperature for testing brine ?

In testing the strength of brine it should first be warmed to a temperature of 60 degrees, as the graduations on the salometer are for this temperature.



Rectangular brine tank with expansion coils. Each coil is provided with an expansion valve, the liquid being led directly to the bottom of the coils. The coils are thus operated by the flooded system, and as the brine is taken from the bottom through the perforated suction pipe and discharged into the top of the tank, the countercurrent effect is obtained.

What are some advantages of the brine system ?

(1) One very important advantage that is claimed for the brine system is its ability to store refrigerating energy in the brine tanks, which may be utilized during the night or in case of a stoppage of some of the machinery connected with the plant, or in case of necessary repairs on the compressor.

In some establishments the brine is cooled in the day time and is circulated by the brine pump during the night, thus keeping the cold storage rooms at the required temperature. This saves the expense of a night engineer to operate the machinery, and the brine or circulating pump may be cared for by a fireman or night watchman.

(2) As a fairly good brine may be made from ice and salt even a prolonged shut-down may be provided for, as would not be possible with direct expansion.

(3) There is also much less ammonia required to charge the brine system than the direct expansion system, which lowers the cost of this item of expense.

How does ample pipe service reduce operating expenses ?

Very often refrigerating plants have a smaller amount of piping than is necessary to do the refrigerating work in an economical manner, which results in the compressor running at a higher rate of speed in order to produce the required amount of refrigeration in a given time. It is better to have too much piping in a cold storage room than too little, for the extra cost at the start will more than pay for itself in the end.

How may this be explained ?

The compressor will have to be run much faster in order to carry a lower back pressure to do the required amount of refrigeration. This results in a greater consumption of coal to operate the engine at a higher speed. If the amount of piping is sufficient or even if there is a little more than enough we can carry a much higher back pressure on the system which results in a slower speed of the engine and a reduction of coal consumed. With a higher back pressure a greater weight of ammonia gas will be pumped back to the compressor and the work will be done fully as well and more economically.

What is chloride of calcium ?

It is a deliquescent salt, that is one that becomes liquid by the absorption of the moisture in the air. (See page 38.)

How much water will it absorb ?

An ordinary commercial quality holds about 25% of water, and it will often absorb from one-half to its full weight more, depending on the degree of humidity, etc.

How is calcium obtained ?

The greater portion of the commercial product comes from the waste bittern of salt works, and the Solvay process of soda manufacture, and as a by-product in the manufacture of ammonia from ammonium chloride and lime; in the preparation of potassium chlorate from calcium chlorate and potassium chloride; and in the manufacture of carbonic acid gas.

How is calcium brine made ?

In practically the same way as salt brine. Care should be taken to get the best quality, but even with this there is a sludge that will stop circulation in small pipes, and sometimes good-sized pipes are choked. Place a steam pipe in the tank for dissolving purposes and do not fill the tank full of water after the calcium is placed in it. When the mixing tank is charged, turn on steam until the tank boils, then close the steam valve. Skim off the scum that rises. It will be necessary to wait until the brine cools before pumping into the system. The skimming can be done without heating, but not as much of the impurities will rise as by heating, and not much time is gained, as the dissolving is so much slower. Heating also saves cleaning later. (See page 38.)

How does calcium come from the makers ?

In sheet iron drums weighing about 600 pounds; the iron of which is of light gauge and of no value.

How is the drum opened ?

Laying it on the side, strike it with a sledge hammer, taking care not to hit twice in the same place, as shown on page 422.

TABLE—CALCIUM CHLORIDE BRINE.

DEGREES ON SALOMETER.	POUNDS OF CALCIUM CHLORIDE PER GALLON.	FREEZING POINT DEGREES FAHR.
0	0	32.
4	0.167	31.1
8	0.333	30.33
12	0.5	29.48
16	0.667	28.58
20	0.833	27.82
24	1.	27.05
28	1.167	26.28
32	1.333	25.52
36	1.5	24.26
40	1.667	22.8
44	1.833	21.3
48	2.	19.7
52	2.167	18.1
56	2.333	16.61
60	2.5	15.14
64	2.667	13.67
68	3.833	12.2
72	3.	10.
76	3.167	7.5
80	3.333	4.6
84	3.5	1.7
88	3.667	—1.4
92	3.833	—4.9
96	4.	—8.6
100	4.167	—11.6

A similar table for salt brine may be found on page 412.

Why should care be taken in this respect ?

Because two blows in the same spot have a tendency to pulverize the salt and waste it, unless it is to be immediately used for brine making, when the finer it is pulverized the better.

In about what shape is it needed for use ?

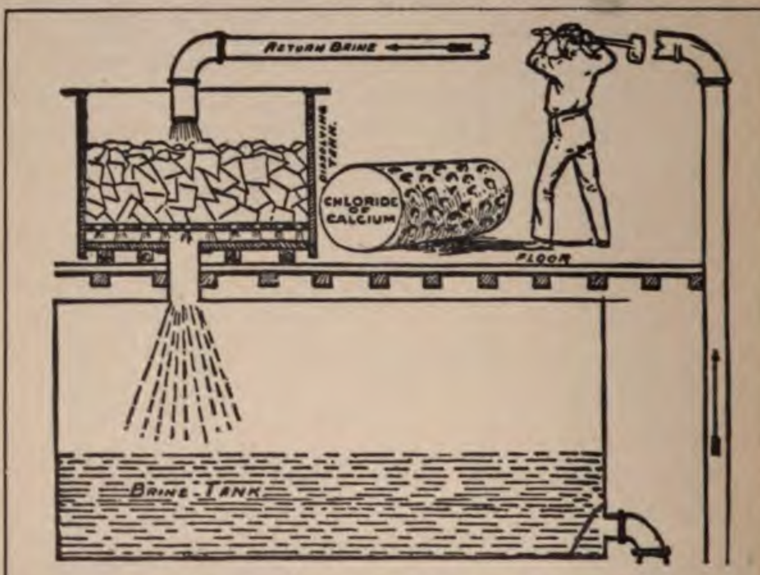
In lumps of ten pounds or less.

What is done when the outside has been thoroughly pounded ?

Stand the drum on end and pry off the top with an old axe or chisel, then cut down the side with the axe.

Why should it be prepared quickly ?

It attracts moisture very rapidly, hence, the lumps should be thrown in the tank as soon as possible.



Method of preparing calcium brine as explained on page 420.

Is chloride of calcium always prepared in solid form ?

It is also manufactured in granular form so that brine may be made more rapidly; it is also shipped, when desired in large quantities, in liquid form in tank cars.

Is calcium brine more difficult to make than salt brine ?

[illegible] because the lumps are larger; the granulated [illegible] much more rapidly dissolved.

Why is chloride of calcium preferable for brine ?

Although it is more expensive than common salt a lower freezing point may be maintained through its use, and it keeps the pipes cleaner.

Is there any way of making the salt brine equally non-corrosive ?

The addition of a small quantity of soda to salt brine may make the two solutions nearly on a par in that respect.

On what does the value of calcium chloride as an absorbent depend ?

On the temperature of the solution from which it was evaporated, also the percentage of impurities which calcium chloride contains.

What is its cost and value as a dryer ?

Its comparative low price and the fact that it is the most active moisture absorbent practicable for common use has brought it into general favor. Chloride of sodium has also great absorbing power for moisture.

Will calcium brine cause rust ?

An iron surface covered with calcium brine will rust very little if at all.

What advantage has calcium brine in low temperatures ?

Sodium brine will freeze at about 7 degrees Fahr., while calcium brine will not freeze at –50 degrees Fahr.

What is the ultimate freezing point of calcium brine ?

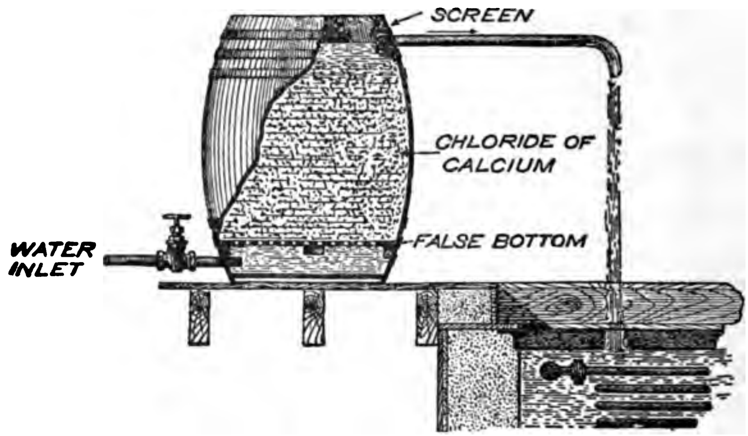
Fifty-four degrees below zero, Fahr., with a 30% solution.

What other advantages has it ?

It is not so liable to deposit crystals in the pipes should the temperature drop below normal, and there is no danger of freezing if reasonable care be used.

What density is required for calcium brine ?

For ice making a 12 to 18% solution is all that is required. A 20% solution will answer for most work, and over 25% is rarely required. As it will carry away more heat units than sodium brine it has an advantage in that it requires a smaller amount, thus giving a saving of power in circulation.



Method of preparing calcium brine from granulated calcium. This is the same process as in the case of salt, as explained on page 408.

Would a more dilute calcium brine stand a lower temperature?

It would. In a general way, a chloride of calcium brine is made by dissolving from 3 to 5 pounds, according to its purity, in a gallon of water. This solution is supposed to have a density of about 23 degrees Beaumé, with a freezing point at about 9 degrees below zero. When salt is used 3 to 4 pounds is dissolved in a gallon of water.

The calcium solution will give the same freezing point with about a pound less of salt to the gallon. Calcium does not attack iron. On the other hand, the brine solution will rust up small leaks in defective fittings which is considered by some to be a point in its favor.

What determines the proper strength of brine required ?

It should be made to correspond to the temperature of the evaporating ammonia rather than the temperature of the coldest brine, as is frequently, but mistakenly, the case.

The proper density of brine, either calcium or salt is determined by the temperature to which it is necessary to be reduced, and the tables will be found valuable in determining the proper strength for different requirements. It should be remembered, however, that a difference of from 5 degrees to 10 degrees Fahr. exists between the temperature of the brine and the evaporating ammon a. and while the strength of the brine may appear ample for the temperature at which it is carried, the lower temperature of the evaporating ammonia may cause it to solidify within or upon the surface of the evaporator.

It is, therefore, necessary in determining the strength of brine, to consider it with reference to the evaporating pressure of the ammonia as well as its own temperature.

What is the Linde method of cooling the brine ?

Whereas in the brine pipe system the ammonia coils are placed in a tank and surrounded by brine, and in the expansion pipe system the ammonia pipes are placed direct in the rooms, in their air circulation system they place the brine separately in a shallow tank, and the ammonia coils over this, open to the air. The brine is then pumped out of the tank and allowed to run over the ammonia coils, and also to fall in a shower through the air. Instead of placing this in the rooms, the whole apparatus or cooler is placed in a separate insulated space, and connected by means of ducts with the rooms to be cooled.

A fan which is in connection with the cooler draws the air out of the rooms, and by forcing it over the coils, over and through the brine, the air is not only cooled but washed, and deprived of all its impurities, so that only pure cold air leaves the cooler and is returned to the rooms from which it was taken.

How does the cost of operation with calcium brine compare with sodium brine ?

The saving in pumping brine is one of the greatest points of economy in using chloride of calcium. It can also be carried at a much lower temperature than salt brine, therefore a proportionately smaller quantity need be pumped. One pound of brine circulated at 10 degrees Fahr., through coils in a room which has to be maintained at 30 degrees Fahr. is as efficient as two pounds circulated at 20 degrees Fahr.

Calcium brine is a much more fluid, oily liquid than salt brine, and will flow through the pipes with less friction, and thus, the saving at the brine pump is marked.

A calcium chloride brine testing about 80 degrees salometer has the same freezing point as a salt brine testing 100 degrees salometer. It will be noted that the salt brine is 20 degrees heavier than the calcium brine and yet has the same freezing point. In other words, they will both carry the same units of refrigeration, but if one solution is lighter in density than another solution, the lighter solution will absorb more heat per cubic foot and absorb it quicker.

Consequently, a cubic foot of calcium chloride brine passing through a pipe in a cold storage room will take more heat out of that room than a cubic foot of salt brine would, and do it quicker. This means that it is not necessary to pump the brine as fast. The result is, less power required for pumping and a reduction in the fuel bill; also an increase in refrigerating capacity.

How is lump calcium used in air cooling ?

Where the indirect system of refrigeration is used, in which the cooling coils are massed in closed coil chambers, through which the air from the rooms is forced by blowers, the air is often passed through a tank or enlarged air-duct, in which trays of chloride of calcium are placed.

When is calcium brine liable to make trouble if it is too strong ?

When pumping, as it will collect and crystallize in the valves and cylinders of the pump and cause a breakdown.

How should the circulation of brine be governed ?

It is necessary to supply only enough to produce the desired temperature. A coil that is once frosted is doing all that can be expected of it and there will only be a loss in circulating more brine through the system.

How may the flow of brine be estimated ?

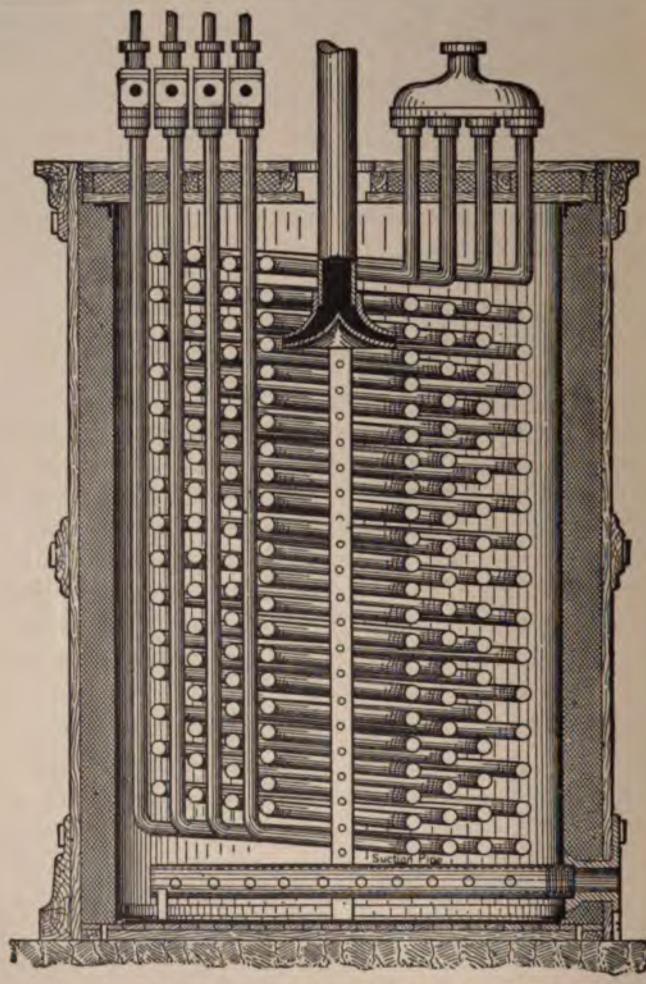
If a coil is frosted its entire length and there is doubt as to the amount of brine circulating through it, simply check the flow until the frost leaves that end of the coil which is nearest the main return pipe, to the brine tank. In this manner it is possible to adjust the flow of brine. When the coils are fully frosted there is no certain method of telling whether one coil is getting more brine than another. A good rule to follow when first putting any particular coil into service is to increase the amount of brine circulating through it, a little at a time, until the coil is nearly frosted. It will then be known just how much brine is passing through that particular coil and the amount can be increased or decreased as may be necessary.

Is the brine system more expensive to install than the direct expansion ?

The installation of the brine system is much more expensive owing to the larger quantity of pipe required to do the same amount of refrigerating work, to say nothing of the additional tanks, pumps, fittings, etc.

What kind of pipe should be used for brine coils ?

Ordinary standard pipe and fittings are sometimes used, and for calcium brine, will last a number of years. For salt brine, however, galvanized pipe and fittings should be used.



Circular brine tank with expansion coils and insulation. The pump draws the brine through the perforated suction pipe at the bottom, and after being circulated it is returned to the tank through the pipe entering at the top.

The ammonia passes through four expansion valves and coils as shown.

If more than one freezing coil is in the brine circulation what provision should be made ?

Regulating valves should be placed near the inlet and outlet of each coil, so that the brine may be well distributed over the entire system.

What can you say of calcium as an absorbent of moisture ?

Calcium has a great affinity for moisture and will absorb it from anything within reach of its influence. It will take the moisture from the hands and from leather so that if shoes get any of it they will shrink and be spoiled; therefore care should be used in handling it.

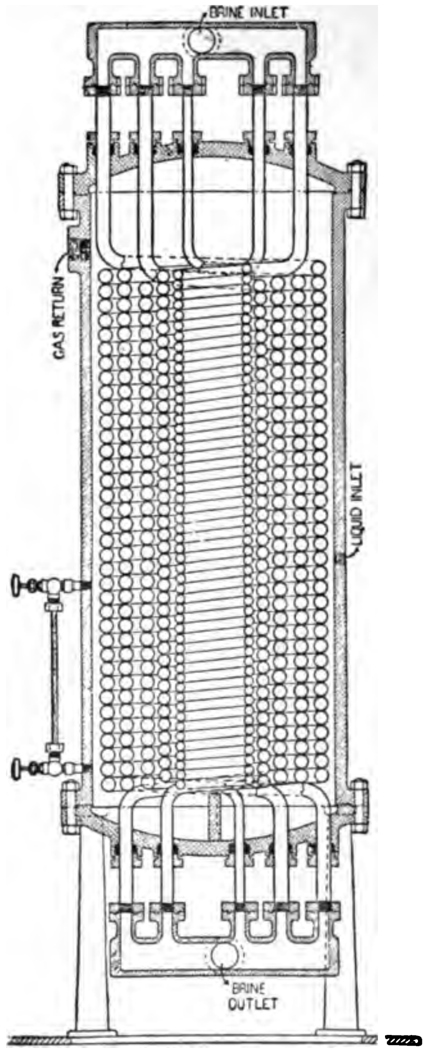
How is this property made useful in regulating humidity ?

This property makes it valuable in removing moisture. In directly refrigerated rooms, in which the cooling coils are placed in the rooms to be cooled, calcium can be placed in pans on the floor or in trays suspended from the ceiling. For intercepting the moisture most effectually, the calcium should be placed in the part of the room where the air circulation is greatest, but it has such an affinity for moisture that it will attract and absorb it, no matter where placed.

How may it be used in keeping pipes free from frost ?

Brine circulating pipes can also be kept free from frost by coating them at intervals with a very strong solution of chloride of calcium; the moisture precipitated on them will not freeze and form frost, but will be absorbed by the calcium and drip off the pipes.

This can be done even after the pipes are coated with frost and the frost will soon be absorbed and leave the pipes bare. It is best, however, to coat the pipes with calcium before starting to cool the room, then two or three applications of brine during the season will keep them clean. This plan is especially adapted to small rooms where the coils are placed over water tight floors or pans to catch the drip.



Vogt Cylindrical brine cooler. The ammonia enters the shell **near** the bottom through an expansion valve, the gas being **taken off** near the top. The brine enters the coils through the **header** at the top and is taken up by the pump from the **bottom** header. The shell should be well insulated to **prevent the** a... ...m taking up heat from the atmosphere.

What is the most approved method of doing this?

Perhaps the best system of using chloride of calcium for reducing humidity is one designed by Madison Cooper, in which the calcium is placed in perforated troughs over the cooling pipes in such a manner that the brine formed by absorbing moisture will trickle down over the coils and cut off the frost. This not only reduces the humidity of the air but increases the efficiency of the coils from 15 to 25 per cent., and will result either in a lower temperature in the rooms or a slowing down of the brine pump to maintain the same temperature.

Can the brine as thus employed be used again?

The objection to it is that the germs taken out of the air in the humidity might be given off again, but as the evaporation of the water requires a high temperature they would probably be destroyed.

Is it practicable to buy calcium with a guarantee as to its commercial value?

The thing that the engineer should demand is that a certain number of pounds of calcium chloride will make a certain amount of brine with a certain freezing point. If the engineer wants to make 1000 gallons of brine, which will have a freezing point of zero, he can have the manufacturer guarantee that a certain number of pounds will make that solution. He should also demand calcium chloride with the lightest density and the lowest freezing point for that density.

How should the piping be arranged in the refrigerating rooms?

In short lengths, connected to headers or manifolds for supply and return, so that any length may be cut out for cleaning or repair.

Each pipe should have a right-angle turn between the manifolds, the latter being placed at right angles to each other, this will facilitate removal of any pipe, and allow freedom for expansion.

What change has been made in the brine tank and how has it been brought about ?

The use of chloride of calcium brine has enabled refrigerating engineers to develop and perfect the brine cooler until it is now recognized as a part of the equipment of a standard refrigerating plant.

How is the brine cooler constructed ?

It may be either of the shell and coil or concentric tube type, being very similar in many ways to the condensers.

How efficient can the brine cooler be made to be ?

It is possible to get an outlet brine temperature within three degrees of the temperature of the ammonia.

Why does the use of a brine cooler require calcium brine ?

Because salt brine would freeze in the coils.

What is the difference between a brine tank and a brine cooler ?

In the former a tank of any convenient shape is filled with the brine which is cooled by the evaporation of ammonia as it passes through a coil in the middle of the tank; in the brine cooler the ammonia vaporizes in a closed cylindrical tank while the brine passes through the central coil.

It is more efficient than the tank plan but it requires the use of calcium in order to avoid any danger of freezing the brine in the coil.

Describe the shell and coil type of brine cooler ?

In this case the brine passes through a series of coils and the ammonia evaporates within the surrounding shell, the whole apparatus having an insulating covering, the same as the regular form of brine tank. The shell is made of refined charcoal cast iron and the coils of best wrought iron extra heavy pipe. The ends of the coils pass through stuffing boxes in the heads and

are connected top and bottom to brine headers. The brine is pumped through the coils in a downward direction.

Liquid ammonia is fed into the shell by an ordinary expansion valve near the lower end of the shell, and the gas taken off through the pipe to the compressor. A purge valve, for drawing off the impurities, is placed at the lowest point in the bottom head, and a second valve, at the top, for gas and air. The shell must be well insulated to avoid loss of efficiency.

Describe the double pipe brine cooler ?

This type of cooler is made up of two series of pipe, one within the other. The brine solution enters at the bottom, and is circulated through the inner or smaller pipes. The ammonia is expanded into the annular space between the two pipes, entering at the top of the cooler.

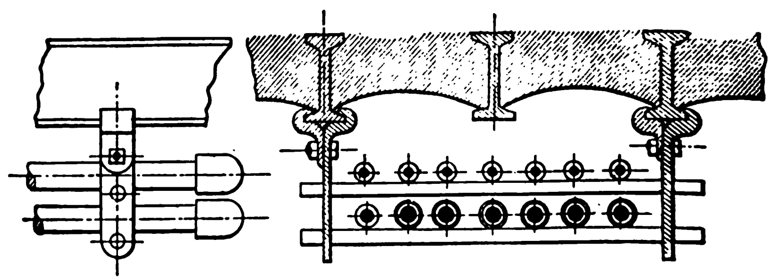
As the outer surface of the pipes act as a refrigerant, it is sometimes desirable to take advantage of this by placing the exposed coolers within a room that is to be cooled, otherwise the space wherein the cooler is placed must be insulated to obtain best results, unless brine is run over the outside the same as water over an atmospheric condenser.

What are the important advantages of the brine cooler over the brine tank ?

The brine cooler has two principal advantages over the regular form of brine tank. First, the brine in passing through the coils is divided into a number of small streams, and is thus mixed and churned so that practically all of it is brought in contact with the cool pipes and gives up more of its heat than in a tank where the movement is very slow. In the latter case, as there is a large body of brine with scarcely any movement, the brine immediately in contact with the pipes may be quite cold, while its temperature rises as the distance from the pipes increases.

The second advantage comes from the fact that there is more space for ebullition or boiling to take place in the shell of the cooler than in the coil in the brine tank, and less liquid ammonia is carried over into the compressor.

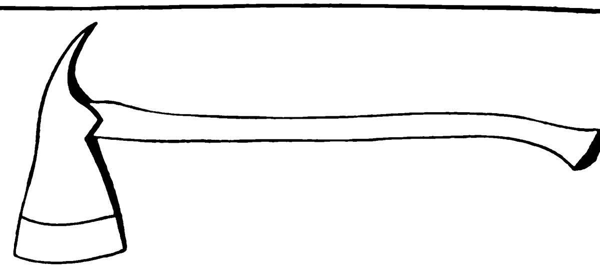
The brine and the ammonia flow through the cooler in opposite directions, the coldest brine meeting the coldest ammonia and the warmest brine the warmest ammonia, thus making possible an exchange of heat on the counter current plan.



Method of suspending refrigerating coils from ceiling of cold storage rooms.

How should pipe be tested ?

It should be tested both before and after being put in a sys tem. Hydrostatic pressure is used, also air pressure under water varying from 500 to 1000 pounds. For a completed system 300 pounds air pressure is used.



Ice Axe.

MECHANICAL ICE MAKING.

Is water that is fit for drinking always suitable for ice making?

Not always, the presence of air and a small per cent. of mineral matter is perhaps an advantage in drinking water, but the former will cause air bubbles in ice; the latter may interfere with its clearness.

How do natural and manufactured ice compare?

The latter is purer and also free from bacterial life. If frozen without holes or cracks there is no difference in their keeping qualities.

How much ice will a cubic foot of water make?

It expands about 8½ per cent. in bulk, by freezing, but there is no change in weight.

What does a cubic foot of water weigh at its point of greatest density; i. e., 39 degrees Fahr.?

About 62½ pounds.

What does a cubic foot of ice weigh?

About 57½ pounds at 32 degrees Fahr.

How much water is required for each ton of ice?

Three or four gallons per minute for every ton of capacity of the plant, and the water should be of a quality suitable for boiler purposes.

How much water is needed for a ton of ice?

About 2400 pounds. This allows a margin for waste.

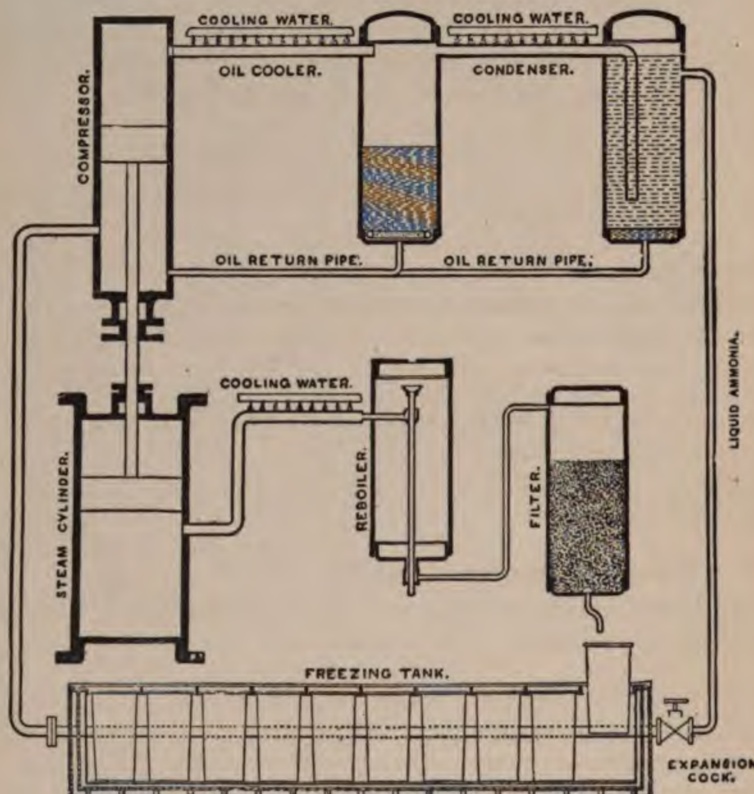


Diagram of a "De La Vergne" ice making plant, showing the distilling system and freezing tank.

What should be carefully guarded against in ice making?

Any taint in the water, which is shown by the presence of ammonia—especially albuminoid ammonia—of nitrates and chlorides, that would indicate the presence of pathogenic germs, that is, those producing disease.

How is the water for can ice obtained in a compression plant?

A little more than half the distilled water may be obtained from the exhaust steam of the compressor.

What is necessary if using exhaust steam for ice making?

To remove oil and grease from the steam.

What filtering substances are used in ice making?

Sponge, charcoal, sand, and sometimes boneblack. In special cases alum is employed.

What is an objection to a boneblack filter?

The water, if containing carbonic acid gas, may combine with the lime of the bone and form carbonate of lime which would cause a white core in can ice.

Why is ice frozen in warm climates more likely to be clear than if made in a cool climate?

Because the quantity of air held in water decreases as its temperature rises.

How can water be deprived of its air?

1, By boiling; 2, by exposing it to a high vacuum; 3, distilling it under exclusion of the atmosphere.

In what way may clear ice be produced?

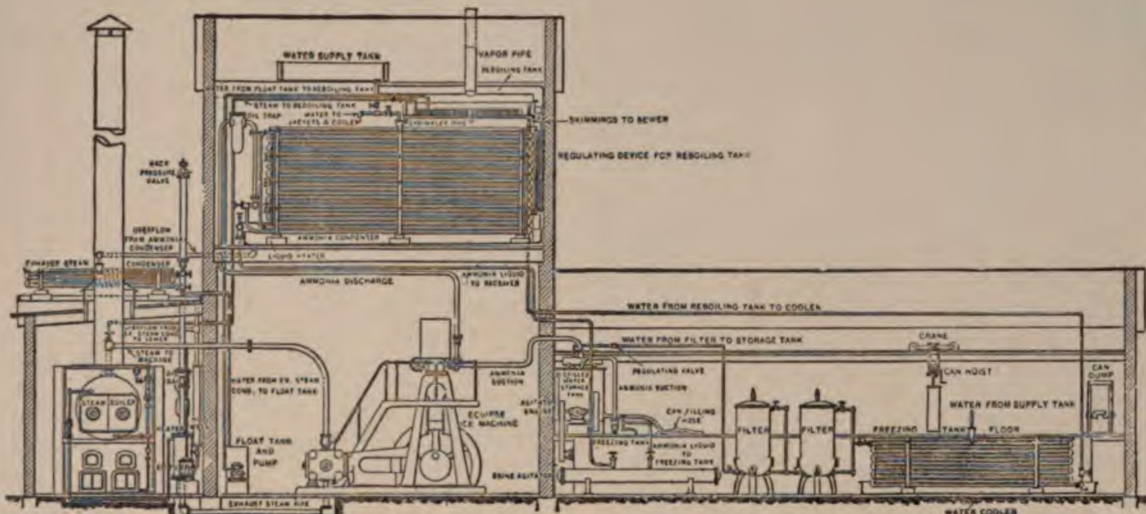
By freezing at, say, 24 degrees Fahr. or above, by means of a paddle or agitator in the can, or by admitting air at the bottom of the can.

What two principal names are given to artificial ice?

"Can ice" and "plate ice."

What system is most largely used?

The can system, where galvanized cans are suspended in cold brine until the water in them freezes.



Sectional elevation of a complete "Eclipse" ice plant for can ice.

Describe the can system.

Galvanized cans or moulds are filled with water, after they have been suspended the proper depth in a tank of brine, the brine being cooled by a direct expansion system in the freezing tank.

What determines the size of the cake?

The local preference; the three-hundred pound cake being the most largely in demand.

TABLE OF SIZES OF ICE CANS.

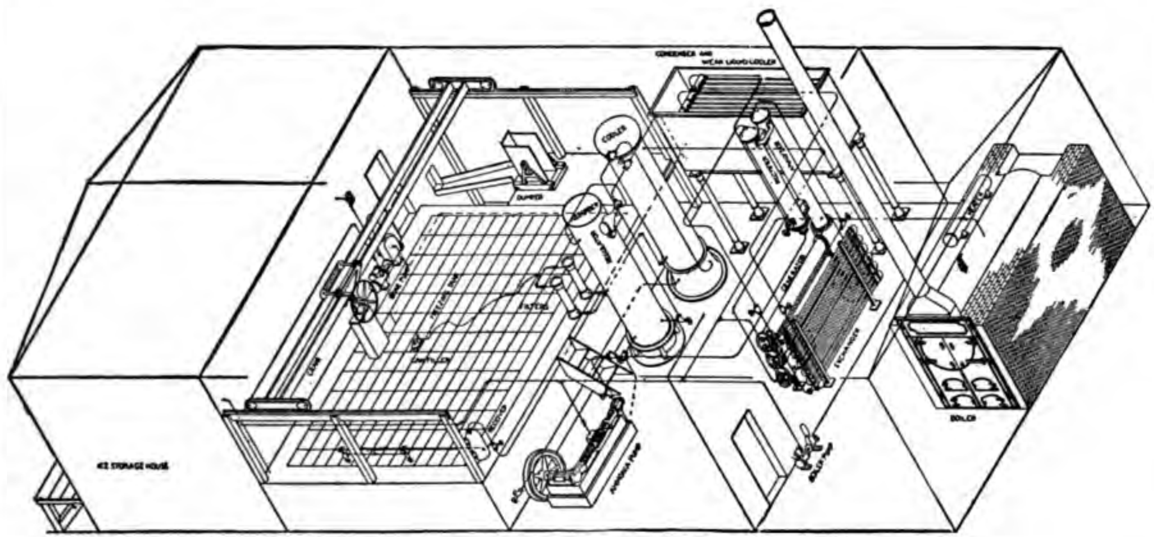
Weight of Cake of Ice	Inside Dimensions			Length Over All	Thickness of Material U. S. Standard Gauge	
	Top	Bottom	Length		Sides	Bottom
50 lbs.	8 x 8	7½ x 7½	31	32	No. 16	No. 16
100 lbs.	8 x 16	7¼ x 15¼	31	32	No. 16	No. 16
200 lbs.	11½ x 22½	10½ x 21½	31	32	No. 16	No. 16
300 lbs.	11½ x 22½	10½ x 21½	44	45	No. 16	No. 16
400 lbs.	11½ x 22½	10½ x 21½	57	58	No. 14	No. 14

The above sizes are in accordance with the standard adopted by the Ice Machine Builders Association of the United States.

Cans are made throughout of galvanized material, well riveted and soldered, and guaranteed tight. Cans made of No. 16 gauge material will be turned over top and bottom. The 200, 300 and 400-pound cans have ¼ x 2-inch galvanized bands around top. Small sizes have ¼ x 1¼-inch bands; ⅝-inch lifting holes are punched through bands.

Are the cans made a little large?

Yes, they will thus hold about five per cent. more than thei rated capacity, providing for loss in thawing.



Perspective plan view of an absorption ice plant showing the complete apparatus and piping.

What is the time required for freezing?

It varies from 40 to 60 hours, it depending, of course, on the thickness of the cakes. The longer the time a given thickness is allowed to freeze the better the quality.

What is the mathematical formula which applies in this case?

The time for freezing different thicknesses is proportional to the square of the thickness, that is, eight inch ice will require four times as long as four inch ice.

How are the cakes removed?

The cans are drawn out of the brine and sprayed with, or dipped into, warm water which loosens the ice so that when the can is inclined on its side the cake of ice slides out, the can being made tapering in shape so as to facilitate the movement.

How many cans per hour can one man handle with a hand hoist?

Ten to fifteen cans.

Is the temperature of the water for ice making of importance?

It should not be lost sight of that it is better and cheaper to do all the work possible outside of the freezing tank, that is, to put the water into the cans at as low a temperature as possible.

How are the cans filled?

By means of a can filler which is so constructed as to automatically shut off the water supply when the can is filled to the proper height. The filler is inserted in the can and the water turned on. As the can fills the ball floats and rises until the can is filled to the right depth, when the valve is automatically closed.

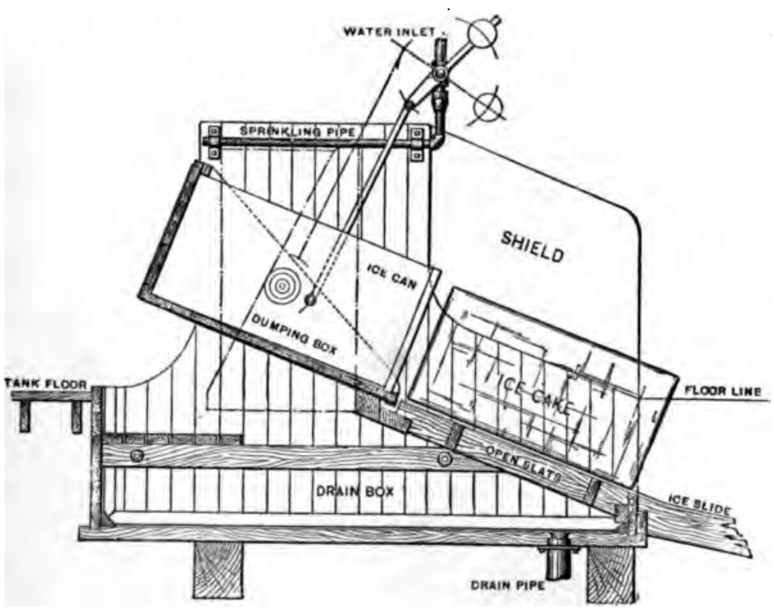
What does a salty taste in the ice show?

A small leak in a can which admits brine.

[redacted]

When are cans properly filled ?

The depth at which the brine is carried in the freezing tanks is an important feature in obtaining the quantity of ice the machine is capable of making. The brine should come as close to the top of the can as possible, and should be somewhat higher than the water in the can, since allowance for expansion as the



Cross section of a can dumper. The dumping box is connected by a link to the valve in the sprinkling pipe, thus as soon as the box is turned into the position shown the valve automatically opens, and hot water is sprinkled over the can and the cake of ice is thus loosened.

water freezes is made when the cans are filled. Cans that are properly filled with water will be even full of ice when frozen. It may take some experimenting to find the exact quantity of water required, but the time and trouble will be more than paid for in the increased yield of ice.

What is the reason for the quick melting of ice cakes, which sometimes, but not often, occurs?

Probably the cake had not completely closed in the center, or it may have had considerable air in it.

What is the cause of cloudy or milky ice?

It is caused by the presence of air. This may be due to deficient re-boiling, the overworking of the re-boiler, or more likely than either, to an insufficient supply of steam to the distilled water condenser, in which case the rapid condensation of the steam causes a vacuum and air is drawn in.

What is the cause of the white core?

Carbonate of lime and magnesia in the water. In many cases it comes from overworking the boiler, carrying too much water, and also from not "blowing off" often enough.

What is the reason of a red core which is occasionally seen?

Carbonate of iron which may come from scale on the pipes and which impregnates the steam, thence appearing in the center of the ice cake.

Why is a high and low water alarm useful in an ice plant?

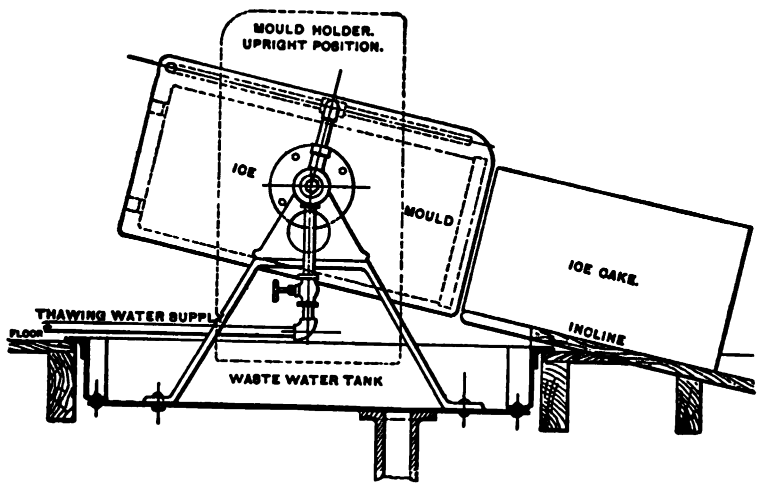
It is desirable, especially the high water alarm, where direct steam is used in the generators, because, should the water in the boiler get too high, the steam passing through the generator coils would become saturated and instead of being condensed steam in the distilled water tank some would be simply boiled water and most likely produce opaque ice.

What are the temperatures for ice making?

In the brine 10 to 20 degrees Fahr., should be maintained, and the back pressure in the ammonia coils, say, from 20 to 28 pounds, which is equivalent to a temperature of 5 to 15 degrees Fahr., in the coils.

In ice making what kind of a freezing tank is best?

As wooden tanks do not last long and are liable to leak, they are better made of steel well coated with water-proof paint. Tanks made of reinforced concrete are also recommended as superior to wood.



Can dumper with iron stand and dump box. The control valve of the thawing pipe in this case is connected to one of the trunnions of the dump box.

How is the freezing tank arranged?

The freezing tank contains the direct expansion freezing coils, equally distributed throughout the tank and these coils are submerged in brine. The tank is provided with a suitable frame of hard wood for supporting the ice cans and a propeller or agitator for keeping the brine in motion; the brine in the tank acts as a medium of contact only, the ammonia evaporating in the freezing coils extracts the heat from the brine, which again absorbs the heat from the water in the cans, thereby freezing it.

How about the size of the ice tank?

The tank itself should not be much larger than is necessary to hold the cans, the coils, and the agitator. About two inches should be left between the moulds and three inches between the pipes and the moulds.

How is the tank most efficiently insulated?

By twelve to eighteen inches of good insulating material on each of the sides and not less than twelve inches under the bottom.

How much pipe is required in the tank per ton of ice making capacity in 24 hours?

In round figures about 220 feet of 2-inch or 350 feet of 1¼-inch for each ton capacity in 24 hours.

How is the pipe arranged in the tank?

So that every can has a run of pipe on each side, preferably the wide side.

How should the flanges of the pipe in the tank be protected?

By a suitable guard; ice cans sometimes catch in the bolts of flanges and, filling with water, drop, thus frequently breaking flanges, bending pipe and puncturing the can.

How are the covers of ice tanks made?

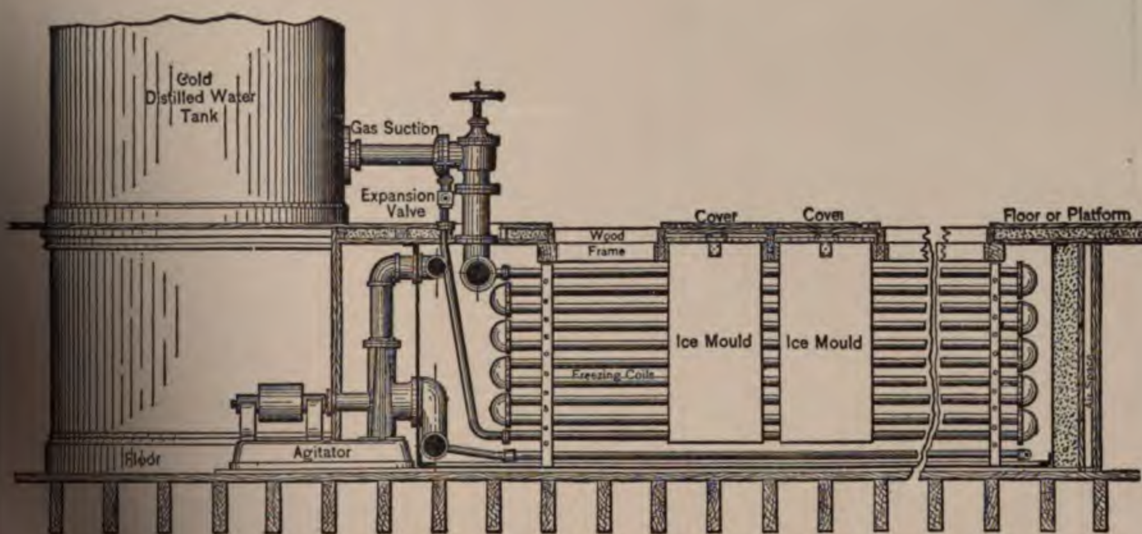
The grating to hold the cans in the tank is properly made of oak, well jointed, and the cover part made of two thicknesses of two-inch dressed oak.

Should ice tank lids be insulated?

It would be economy to have two inches of insulation.

How should the covers of the tanks be treated?

The bottom and sides of the bath lids should be cleaned, also the timbers that the lids rest on.



Cross section of freezing tank, showing a centrifugal agitator. The gas suction is carried through the water storage tank thus forecooling the water.

Describe the brine agitator and tell why used?

Brine agitators are attached to ice freezing tanks and are used to keep the brine in circulation, thereby maintaining a uniform solution and temperature. Brine agitators properly placed in the brine tank will cause the cold brine to circulate so that the most heat possible will be absorbed by the ammonia in the coils, and also by the brine from the water in the cans.

Should the expansion coils in the freezing tank be examined periodically?

If the expansion coils in the freezing tank have been neglected for several seasons, it would be well to remove the brine, examine carefully all the coils, disconnect the top and bottom manifold, clean the coils externally and see that there are no traps in the pipes; then blow them out with steam pressure, and if the weather is cold follow with air pressure to prevent any remaining condensation freezing. After they are all blown out and cleaned externally, test them to not less than 250 lb. pressure, then allow them to drain, or blow out again with air pressure.

How may small leaks be stopped in a brine tank?

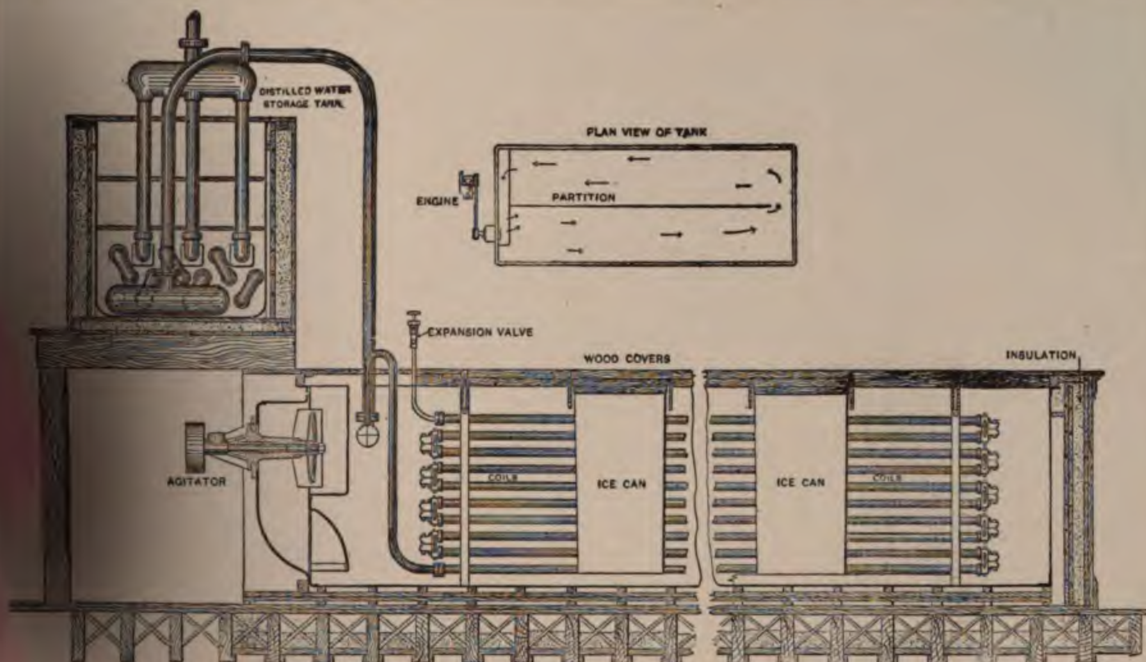
By the use of bran or corn meal which can be applied through a piece of gas pipe.

How is carelessness sometimes the cause of dirty ice?

A frequent source of dirty ice and bad butts is due to failure to keep the can lids clean, also the timbers the lids rest upon. If the water stands the test as it goes into the cans and the ice shows up bad it is evident that the impurities enter the water after it reaches the can. Opaque ice is caused by not keeping the can filler and hose air-tight, or by agitating the water too much when withdrawing the filler from the full can.

How do impurities often reach the ice cans?

Through the workmen who carry soil from the streets, stables, etc., and walk over the lids of the cans.



Detail arrangement of freezing tank of an Eclipse ice plant, showing the arrangement of the cans with covers, also the brine agitator. The agitator is in the shape of a propeller which keeps up a continuous circulation of brine between bottom and top of tank.

How may precautions be taken to avoid this?

By having a faucet with a short hose at hand in an ante-room to the freezing rooms, and requiring the men to clean their boots before entering; the floor of this ante-room should be cemented and provided with a proper drain.

How may leaky ice cans be repaired?

By soldering; now, since the cans are made of galvanized iron, muriatic acid in its raw state should be used, as acid killed with zinc would have no effect upon the zinc used for galvanizing and thus the solder would only stick to the zinc coating and easily peel off. If, however, raw acid is used, the acid will dissolve the zinc around the leak, and allow the solder to adhere to the iron.

Should raw acid be used on bare iron?

In places where the zinc coating has come off the iron, killed acid should be used. The term "killed" acid is applied to muriatic acid in which as much zinc as the acid will take up has been dissolved.

If it is necessary to work by hand in brine how should it be protected?

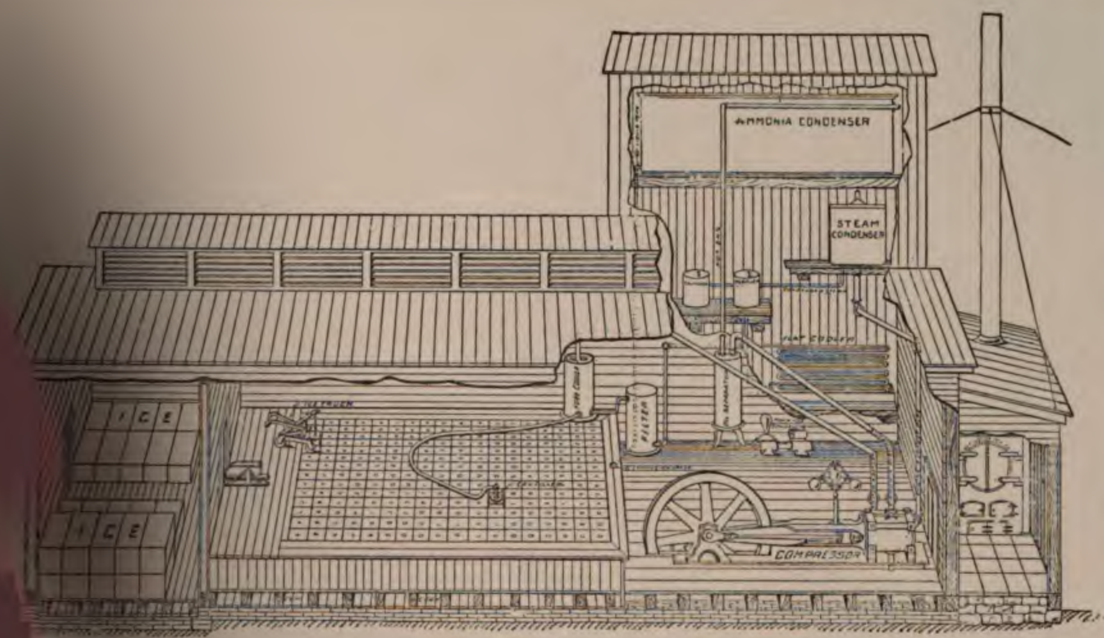
The hand and arm should be smeared with cylinder oil, lard or tallow.

What is important in running an ice plant for best results?

To work day and night.

Why is this one of the most important factors of cost?

The cost of ice is governed probably more by the daily average of output than by any other item. While the cost of labor, coal, water, ammonia and other supplies will vary in different localities, the management has direct control of the quantity of ice manufactured. Therefore, it is desirable that the plant operate to its fullest capacity throughout the season.



Perspective view of the interior of a small "De La Vergne" ice plant.

In estimating the cost of ice what expenses are to be considered?

The ideal ice plant is the one which can produce a ton of ice for the least money, when the following costs are taken into consideration: The interest on the total cost of the plant; the allowance for wear and tear; the labor required and the fuel and supplies needed. These expenses should be taken for a stated period of time and divided by the total amount of ice produced for the same period. The result of this calculation will determine the actual cost per ton.

What is the cost of manufacturing ice?

It varies greatly, according to circumstances, from seventy-five cents to two dollars and fifty cents per ton.

Is a statement of ice produced per ton of coal a safe criterion as to economical working?

No, because a larger output of ice in one case may be more than balanced by increased cost of labor, and other items of cost.

What, then, is the only proper comparison?

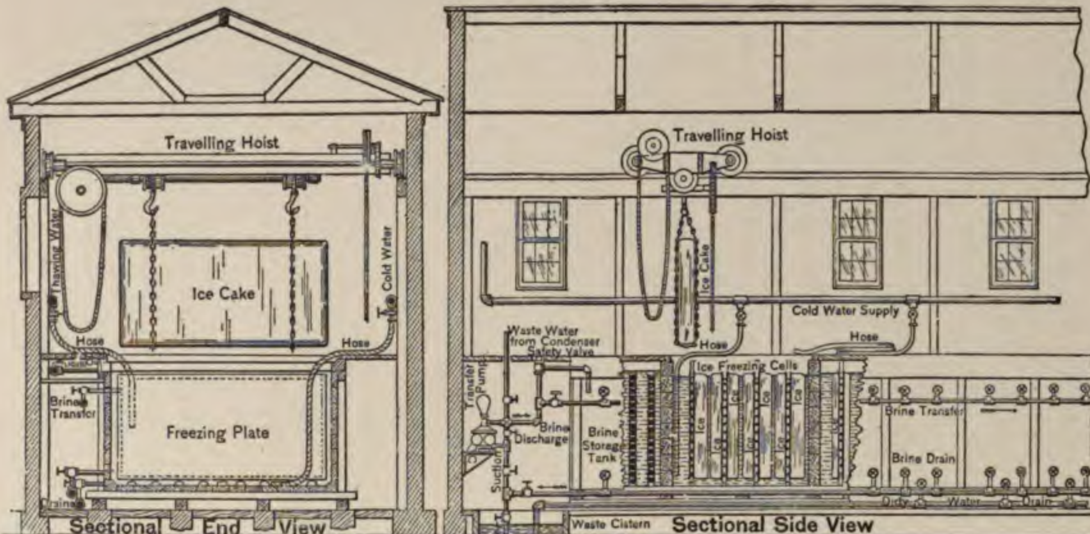
The total cost per ton of ice manufactured.

Are there several methods of making plate ice?

Yes; 1, the direct expansion plate system; 2, the direct expansion plate system using "still" brine; 3, the brine cell plate system; 4, the brine coil plate system, and 5, the block system.

Describe how they differ from each other.

The direct expansion plate system is the simplest in construction and consists of direct expansion zig-zag coils with one-eighth-inch plates of iron bolted or riveted in place. The thawing off of the face of the ice is accomplished by turning the hot ammonia gas from the machine direct into the tank



Section'l elevations of freezing cells of an Eclipse plate ice plant. The ice plates are hoisted by means of the traveling hoist after being thawed off the freezing plates by passing hot brine through the coils. The freezing plates with their coils are shown in heavy black lines with the ice forming on both sides af them.

The direct expansion plate system with still brine, known as the "Smith" plate, is similar in construction, excepting that the coil is immersed in a brine solution contained in a water and brine-tight cell. Thawing off is accomplished by turning hot gas into the coils.

The brine cell plate system consists of a tightly caulked and riveted cell or tank about four inches thick, provided with proper bulkheads or distributing pipes, to give an even distribution of brine throughout the plate. The thawing off of the face of the ice is accomplished by circulating warm brine through the plate.

The brine coil plate system is similar to the direct expansion plate, excepting that brine is circulated through the coil instead of ammonia. Thawing off is accomplished by means of warm brine circulated through the coils.

In the block system the ice is formed directly on the coils, through which either ammonia or brine is circulated. After tempering, the ice is cut off in blocks the full depth of the plate by means of steam cutters, which are guided through the ice close to the coils.

How is plate ice harvested ?

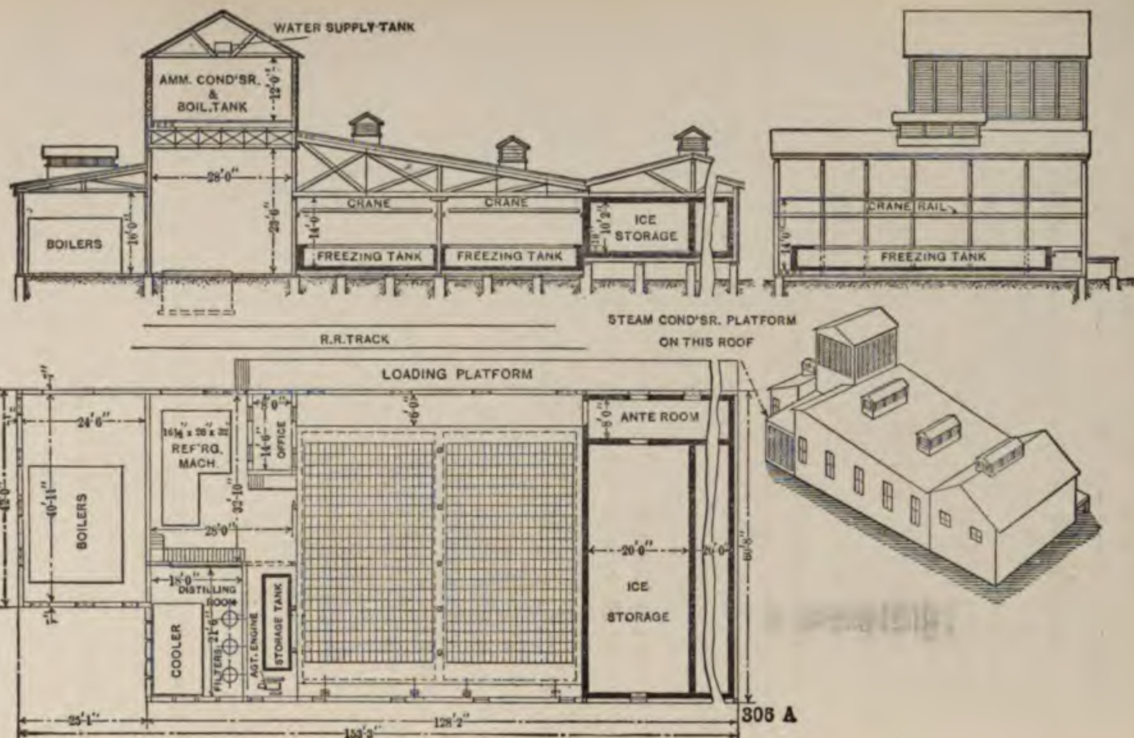
The method is similar in all of the foregoing systems, excepting that in use for harvesting block ice. Some use hollow lifting rods and thaw them out with steam, others use solid rods and cut them out when cutting up the ice, and others again use chains which are slipped around the cake when it floats up in the tank.

What is a common size for plate ice ?

16 by 8 feet, and 11 inches thick; 10 by 14 is also made.

What advantages has plate over can ice ?

As the water is not confined as in a can it will freeze clear and transparent, and for this reason it is not necessary to distill
[illegible] being necessary to filter it.



Plan and elevation of a sixty-ton ice factory.

Which system, can or plate, requires the most space ?

The plate system.

How long does it take to freeze plate ice ?

A plate twelve to fourteen inches thick requires from nine to fourteen days; it is seldom frozen, however, over eleven inches which can be done in seven days at 15 pounds back pressure.

What are its merits and disadvantages ?

The plate system costs more to install but is said to be more economical to work. The ice is clearer as, freezing only on one side, the air and other impurities are forced out.

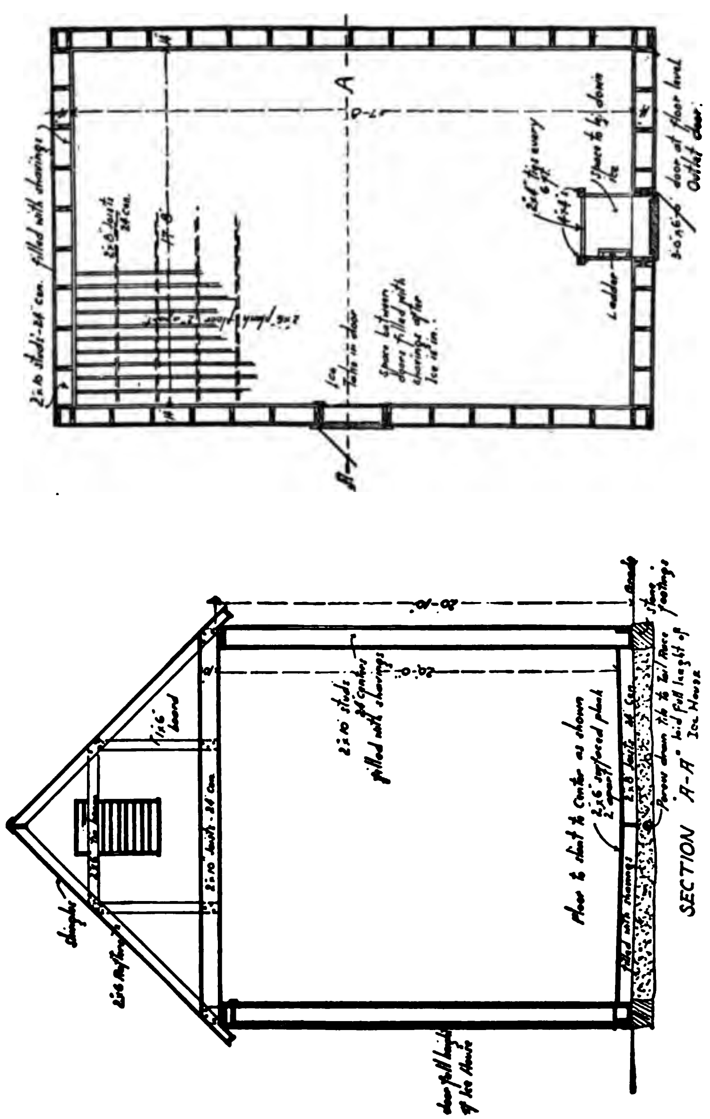
How is the plate ice freezing tank made ?

It does not differ materially from can ice tanks only in being divided into compartments of the required size and number, each compartment being furnished with one or more plates on which the ice is frozen. The compartments are made of sufficient size to hold a supply of ice for one day so that each compartment may be emptied, cleaned and refilled every twenty-four hours.

Describe the process of freezing in plate plants ?

Several vertical hollow iron walls are built in a large tank. The tank is filled with pure well water so that the iron walls are entirely submerged. The hollow iron walls are placed parallel to each other at a distance of from two to three feet. The freezing fluid, consisting either of cold brine or ammonia, is passed through the hollow walls, with the result that the water will freeze on the outside of the walls; the water is kept in agitation either by means of a propeller or pump, or by compressed air, so that the water is kept continually on the move; carrying the air with it prevents it from being frozen in the ice. After the ice is frozen on the walls to the required thickness the freezing fluid is shut off from the walls and a warm fluid passed through instead until the ice is loosened and taken out of the tank.

[redacted]



Plan and sectional elevation of an ice storage house.

How do the plate walls differ in construction?

The construction differs according to the freezing fluid used. If cold brine is used, then the brine has to be cooled in a separate refrigerator from which it is pumped through the walls and back to the refrigerator, the same as is done when cooling rooms by means of brine pipes. The plate walls in such a case are generally constructed of iron. On account of the expansion and contraction occasioned by warm or cold brine being passed alternately through the hollow walls, it is very difficult to keep them tight.

How are the walls made if ammonia gas is used as the freezing fluid?

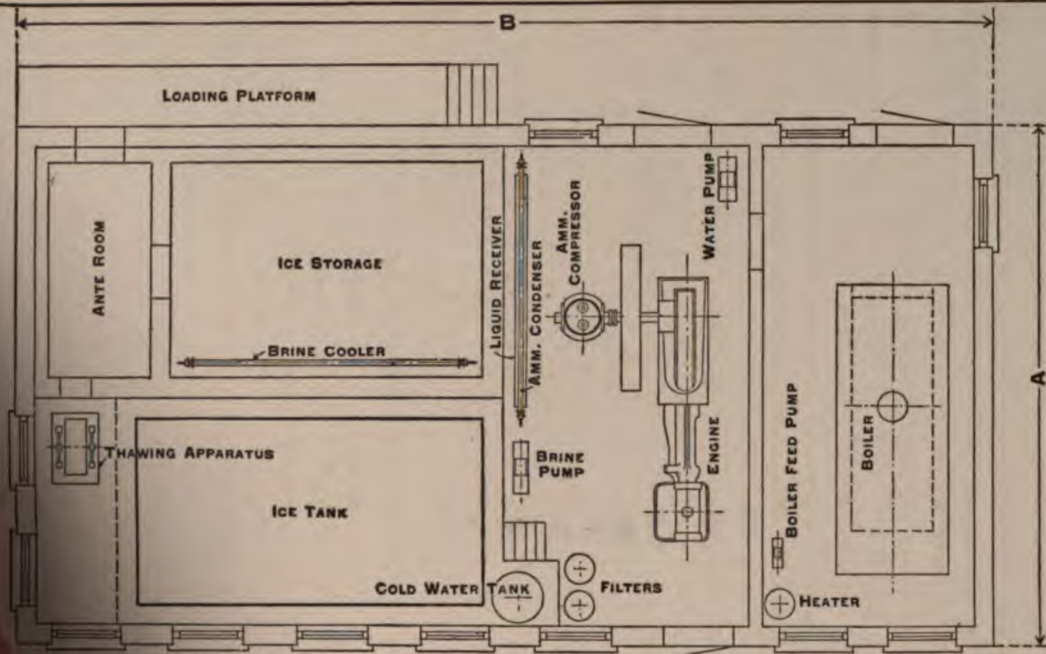
In this case, the walls are built up of expansion pipes, which, connected at each end by return bends, make one continuous zig-zag coil. To get an even surface the coils are covered with thin iron plates on the outside of which the ice is frozen. To loosen the ice, when thick enough, is effected by shutting off the cold ammonia gas and passing hot gas through the pipes instead.

How do heat and cold affect the freezing walls?

To pass at one time cold and at another time hot ammonia gas through the same pipes can only be done by bringing the pipe walls alternately in connection with the expansion and the compression side of a refrigerating machine, that is to say, make the pipe walls act at one time as a freezer and at another as a condenser. To do this special valve connections have to be made, which are complicated, and (to avoid accidents) require careful handling.

How is agitation carried on?

By means of air jets located midway between the plates, sometimes in the center, sometimes three or four feet from one end and sometimes at both ends of the plates.



UND PLAN OF ICE FACTORY GIVING DIMENSIONS FOR DIFFERENT CAPACITIES.

ity in tons	3	5	10	15	20	25	30	35	40	50
ions at A in feet	25	28	32	35	38	40	40	40	48	48
ions at B in feet	50	56	70	75	82	90	100	115	120	130

What change has the Wolf Company made in this process?

To do away with the complicated valve connections and the consequent danger resulting therefrom, they have experimented to construct a plate which would have none of these defects. Their freezing plates are constructed of zig-zag coils, but instead of having the wall consisting of only one coil, they have two, which interlock each other. Further, instead of placing iron plates over these coils, so as to make a smooth outside surface, they fit between the pipes specially rolled channel irons, which, partly surrounding the pipes on the inside, make a smooth outer surface. Through one of the two coils they pass the cold ammonia gas, and therefore use it for the freezing of the ice. Through the other coil they pass warm brine when they loosen the ice from the plates.

How are the plates made into cakes?

Cutting up the plate is accomplished by means of steam cutters, power saws and hand plows. In the block system, however, where the ice is cut off the plate in the tank, it only remains to remove the cakes by means of a light crane and hoist and divide them into the required sizes with an ax or bar.

Should plate tanks be often cleaned?

In making ice from raw water it should be borne in mind that water in freezing throws out impurities, and the water remaining in the tank after the ice is frozen is heavily charged with foreign matter.

What is the best ice for storage?

Clear solid ice without any core.

How should the storage house be constructed?

Very much the same as for natural ice, insulation being the most important point.

How is manufactured ice stored?

Strips of lath, sawdust, hay, straw, and in the South, rice chaff are used for packing it.

How much space should be allowed per ton?

About fifty cubic feet.

How is artificial ice shipped?

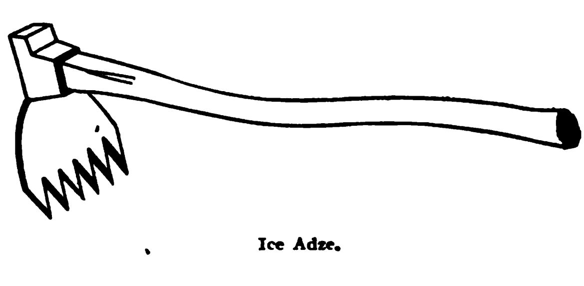
It is usually shipped in cars and packed the same as for storage.

What is the importance of an ante-room in an ice storage warehouse?

An ante-room, cooled by pipe, obviates the necessity of opening too often the main house. A certain amount of ice can be kept in it as may be found necessary.

How about the arrangement of piping, ventilation and drainage?

The pipe should be placed along the ceiling, the house throughly drained, and the highest part well ventilated although care should be taken that warm air is not drawn in below.



Ice Adze.

VARIED USES OF REFRIGERATION.

Before one can properly appreciate the value of refrigeration as an every-day agent for man's use and comfort, it is necessary to form a clear conception of the causes which bring about decomposition and waste. All decaying substances when examined under the microscope are seen to be swarming with micro-organisms which are invisible to the naked eye.

Like all living things, these micro-organisms bring about the chemical transformation of matter by "feeding on," or absorbing substances in one form and excreting them in another, or else producing ferments which bring about these changes.

In the early stages of decomposition, food is often covered with furry growths, commonly known as mould. These are well characterized forms of plant life. They are of considerable importance, as they prepare the way for the development of other more minute organisms and bacteria. If we could only exclude these organisms, it might be possible to preserve even the most perishable of foods indefinitely.

These spores, or seeds, are extremely minute, are always found floating in the air, and are continually settling like dust on every object. Wherever they find favorable conditions and suitable surroundings they quickly obtain a foothold, and breed and multiply. These conditions may be classed under four heads: (1) Supply of suitable food; (2) presence of moisture; (3) suitable conditions of temperature; (4) absence of substances which either kill them or prevent them developing.

Vegetable and animal matter, including foods for human consumption, all provide suitable food for micro-organisms, but it is essential for their development that moisture should be present, hence the primitive method of preserving food by drying, and therefore excluding moisture. Thoroughly dried foodstuffs will keep a long time. The organisms may be there, but they have not a chance for developing.

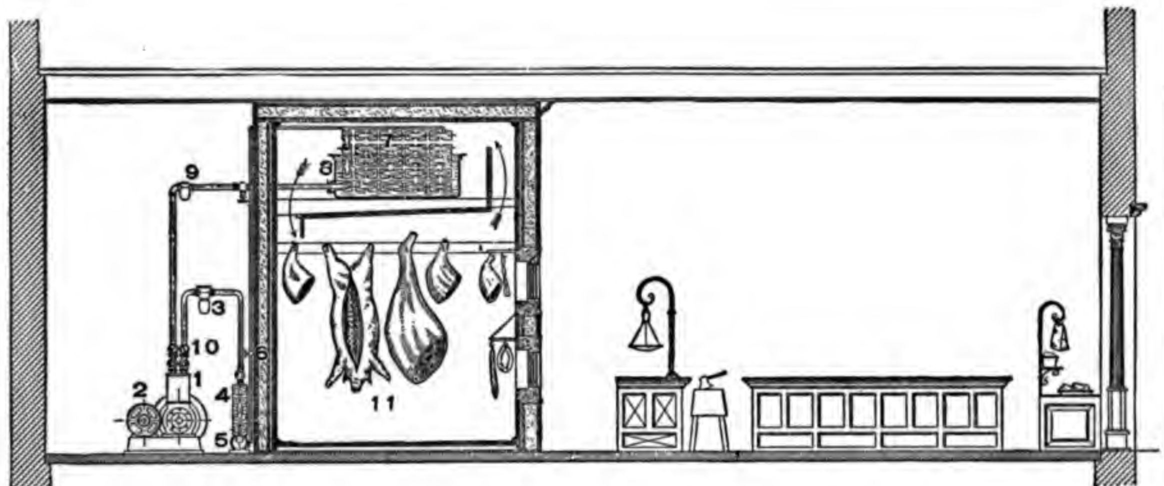


DIAGRAM SHOWING INSTALLATION OF PLANT IN RETAIL MEAT MARKET.

1 Ammonia Compressor
2 Electric Motor.
3 Oil Trap.
4 Ammonia Condenser.
5 Liquid Receiver.
6 Expansion Valve.
7 Direct Expansion Coil.
8 Brine Tank.
9 Suction Scale Trap.
10 Gauges.
11 Refrigerator,

When the true, although invisible, causes of destruction and decay are known and efficient control is applied, and moreover when the machines used in refrigeration are further perfected, then refrigeration will be put to many more uses than those named in the following pages.

How is refrigeration used in the chocolate manufacture?

Large cakes, weighing about two pounds, are cooled in rooms held at 30 degrees, it requiring four or five hours to effect the cooling.

In the dipping and packing rooms about 68 degrees is maintained, with a humidity percentage of 70%. The system is a closed one, the air being largely used over and over.

How is refrigeration applied in the silk industry?

There is danger that the silk worm will hatch from the eggs before the mulberry leaves have reached sufficient maturity to constitute a proper diet. If on account of a backward season the mulberry leaves are delayed a temperature of 32 degrees Fahr., will retard the hatching of the eggs at will, and without harm to the silk worm.

Why is raw silk put in cold storage?

If stored at an ordinary temperature a loss of weight and luster results, caused by the evaporation of the natural moisture and volatile matter. A temperature below 30 degrees prevents the evaporation and maintains the luster. Inferior grades are specially liable to damage when exposed on the shelves for a time, and cold storage is necessary.

Why is refrigerating machinery used in tea-curing factories?

It enables the atmosphere of the hills to be duplicated in the low lands of India, etc.

At a certain stage in the manufacture of tea—when it is being fermented—control of temperature and humidity is very

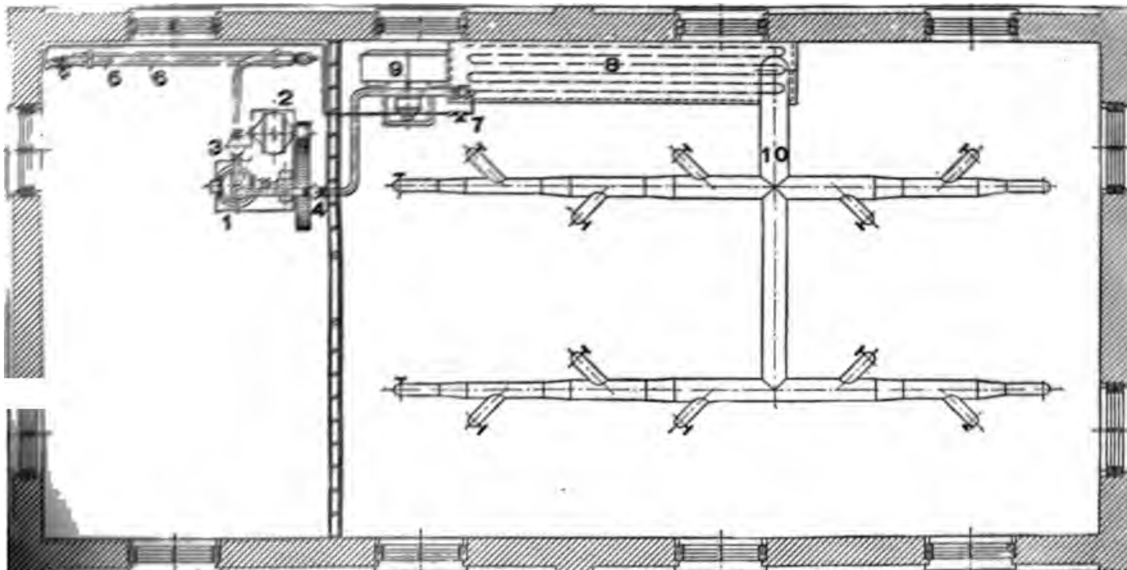


DIAGRAM SHOWING COOLING PLANT FOR CONFECTIONERS.

1 Ammonia Compressor.
2 Electric Motor.
3 Oil Trap.
4 Suction Scale Trap.
5 Ammonia Condenser.
6 Liquid Receiver.
7 Expansion Valve.
8 Coil Chamber.
9 Fan, motor driven.
10 Galvanized Iron Air Ducts.

How is plant growth regulated by refrigeration?

It is used to retard the development of bulbs and flowering plants so as to produce blossoms at the time of the year when they are most in demand. Lily of the Valley is made to blossom at Easter time, and roses which would naturally blossom in summer are delayed until Christmas. Potted plants are kept at a temperature of 30 to 35 degrees, and then put in the greenhouse so as to bring them to flower or fruitage at the date desired, entirely independent of outside weather conditions.

What florists' goods are put in cold storage?

Lily of the Valley pips, November until spring, 25 degrees.
Chinese, Japanese and Bermuda lily bulbs, 34 to 36 degrees.
Wild smilax, 32 to 34 degrees.
Galax leaves, 25 degrees.
Ferns, early in fall or after first frost, 25 to 28 degrees.
Leucothoë, 30 degrees.

Why is dried fruit and other grocers' sundries stored?

To prevent loss of weight by evaporation, and to avoid mould and fermentation. The cold also prevents the development of insect life. The temperature should be from 36 to 45 degrees; even as low as 25 degrees will do no harm.

What is necessary in storing fruits?

The humidity must be carefully regulated so that they will not dry or wither.

How is refrigeration used in champagne manufacture in wine-growing countries?

In the final fermentation, the bottles, after being filled, are inverted, and the yeast falls and collects on the cork; the inverted heads are then placed in glycerine at zero temperature, when the yeast freezes and is then drawn out with the cork without loss of wine.

What is the use of very low temperatures in pharmacy?

A number of preparations (especially narcotics) can be obtained in a chemically pure state by crystallization at low temperatures, say from- 150 to- 300 degrees.

How are these temperatures obtained?

By the evaporation of large quantities of liquid air or such gases as oxygen or nitrogen.

Is liquid air useful for refrigerating purposes?

For special purposes such as the preparation and purification of certain chemicals, for medical purposes and for physical experiments, liquid air and other liquefied gases have many advantages—one is the production of a high vacuum.

In office buildings and apartment houses where the water is cooled what is the amount estimated as needed?

One gallon per person each day.

What is the temperature usually given at the drinking faucet?

Forty to fifty degrees Fahr.

What was one of the first adaptations of mechanical refrigeration in the manufactures?

The extraction of paraffine wax from paraffine oil; this is done by putting a drum or revolving surface of the proper temperature in a bath of the oil. The wax may be scraped off from time to time as it freezes on the surface of the drum.

The wax is obtained in another way by allowing it to crystallize from the oil in a shallow tank which is cooled by jacketed brine.

The wax as it forms is carried by an endless screw in the bottom of the tank to the filter presses.

Can a small creamery use ice as well as refrigerating machinery?

If it is one that handles only from 10,000 to 15,000 pounds of milk per day, and can store ice for $1.00 per ton or less, it can use ice to advantage. On the other hand if ice is expensive, the use of machinery is advisable.

How have the two methods been compared?

The disadvantages in using machinery are: (1) large capital invested, (2) necessity for continuous operation unless provided with large storage tanks, (3) cost of operating in the way of labor, coal, oil, ammonia and repairs, (4) excessive dryness in the refrigerator, causing a great shrinkage of products, (5) some risk of accidents, (6) cost of pumping water, etc. On the other hand, the advantages are: (1) no risks to run in securing cold when needed, (2) practically no variation in its cost from year to year, (3) refrigerator under better control, (4) any temperature desired can be had, (5) as the refrigerator is dryer, there is less liability to butter moulding, (6) less disagreeable labor such as handling ice, (7) cold room can be kept cleaner, (8) no impurities in ice, (9) it provides a more perfect method of cream ripening, which results in a better product, (10) greater economy of space in the cool room. (Cooper)

How may a supply of natural ice be estimated for a creamery?

100 cubic feet of ice per cow per annum will be ample.

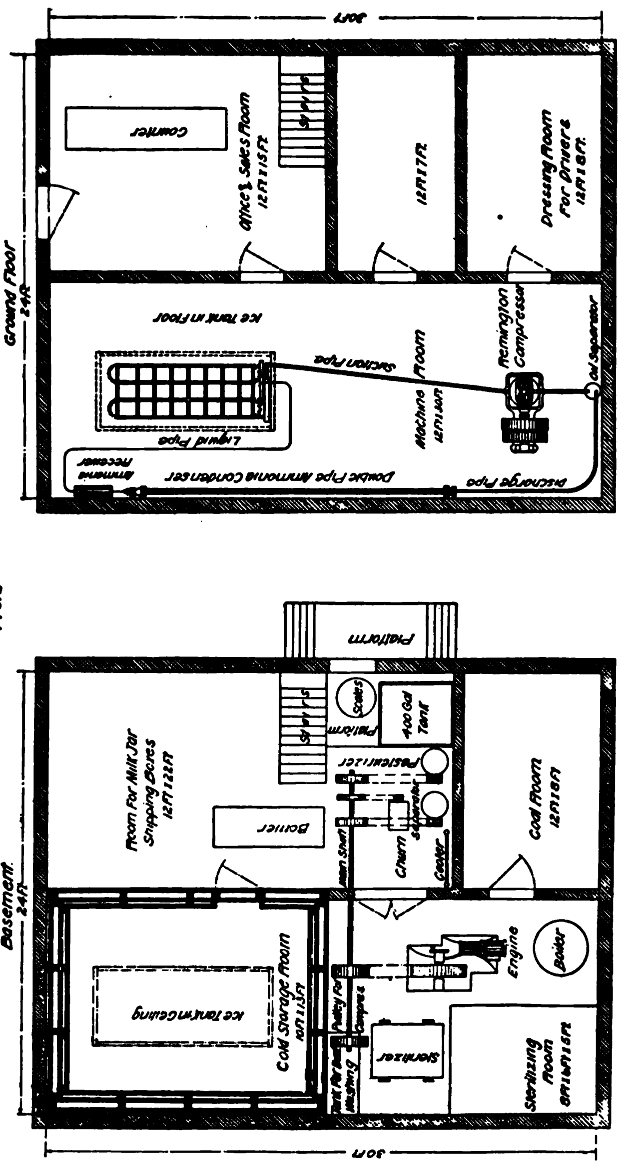
How is milk stored?

It is usually stored for a short time only. It is admitted that in all branches of dairy work, mechanical refrigeration is superior to the use of ice.

Why should fresh milk be cooled?

Because even the best milk contains spores and if their development is not arrested, they will produce bacteria and the milk will sour.

[redacted]



A Complete Dairy Plant.

How is the milk treated when received?

It is first tested for quality, then it is put in a large tank where it passes through three sets of fine strainers. It then goes through coils in a brine tank, and is drawn off in cars which are stored in a refrigerator at 35 degrees.

How is milk shipped as to temperature?

It should be reduced before shipment to 40 degrees.

Outside of this country, where have the greatest advances been made in dairy refrigeration?

Denmark and Sweden have been the foremost in adopting machinery.

How is milk now being shipped in Europe?

It is shipped in the form of frozen blocks.

What is pasteurization of milk?

Heating to a temperature of 180° which destroys, by the way, only the full grown bacteria.

How does it differ from sterilization?

This process requires a temperature of 200° and is intended to destroy all bacteria spores also. In the latter process it is heated up to 200°; then cooled down while the bacteria spores which have not been destroyed have time to develop, when the process is repeated. If now put in hermetically sealed bottles it will keep a considerable length of time.

Has pasteurization been generally adopted?

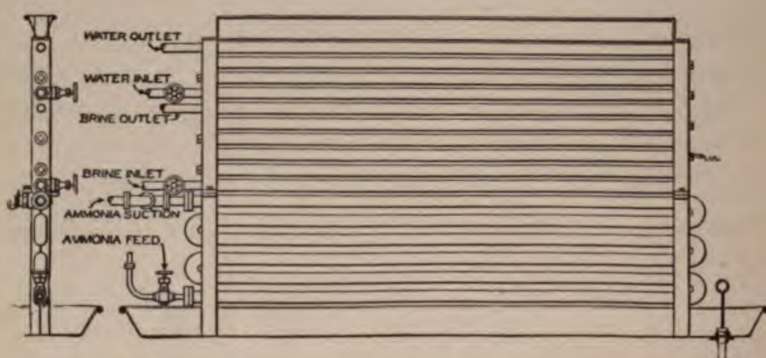
Yes, in the larger creameries of the United States, also notably in Denmark, Holland and Belgium.

[illegible]w does [illegible]cess involve refrigeration?

It is [illegible] be essential to reduce the temperature after [illegible]rization as quickly as possible.

What is the method of cooling in a creamery ?

The cooling is done: 1, either by direct expansion, using a tinned iron pipe coil through which ammonia passes and over which the cream flows, or, 2, by cold brine pumped through a copper coil immersed in the cream. Cream vats supplied with ammonia piping in the water, which fills the space between the



This milk cooler is similar in design to the Baudelot beer cooler, which is the most practical method for cooling beverages where it is desired to reduce their temperatures rapidly without danger of freezing. The sweet water is first used as the cooling medium, next the cold brine and last the expanded ammonia, which finally reduces the milk to the desired temperature. The importance of quickly cooling the warm milk is well known to dairymen, and this cooler, built with the three stages as above illustrated, performs its duty most efficiently. The pipes and bends are polished and where it is required, the water and brine sections are made of copper.

tin and the wood, will hold the cream at proper temperature while ripening. Most of the ripening apparatus can be arranged for brine circulation. The storage room being [illegible] with expansion coils can also be cooled to a lo[illegible] quickly. A brine storage tank is [illegible] which tank contains a large body [illegible]

the freezing point of water when the compressor is running and acts as a cooling agent itself when the compressor is shut down, thus holding the rooms at an even temperature. Still another form of cooling apparatus is shown on page 470.

How must milk be cooled before being made into butter?

The best churning temperature in summer is 48 degrees to 52 degrees. If churned at as high as, say, 65 degrees, the butter will be oily, and there will be a loss in the buttermilk.

Is some form of refrigeration necessary?

In order to make good butter the maker must be able to heat and cool the cream at will. Refrigeration is therefore necessary to its proper keeping quality.

What is the advantage of refrigeration machinery in creamery management?

All creamery men know the importance of being able to control the temperature of the cream while the ripening process is going on, and the need of cooling to check any further fermentation when the proper acidity is reached; these are important points in butter making and can only be satisfactorily accomplished by means of mechanical refrigeration. In no business is temperature control more important than in the handling of milk and its products. The perishable nature of milk and the rapidity with which it deteriorates when exposed to ordinary temperatures makes cooling facilities a necessity.

Why does mechanical refrigeration insure an even quality of dairy products?

A creamery equipped with a refrigerating plant can at all times turn out a uniform grade of butter, whereas creameries without mechanical refrigeration are subject to great variations in the quality of their product, due to weather and temperature changes.

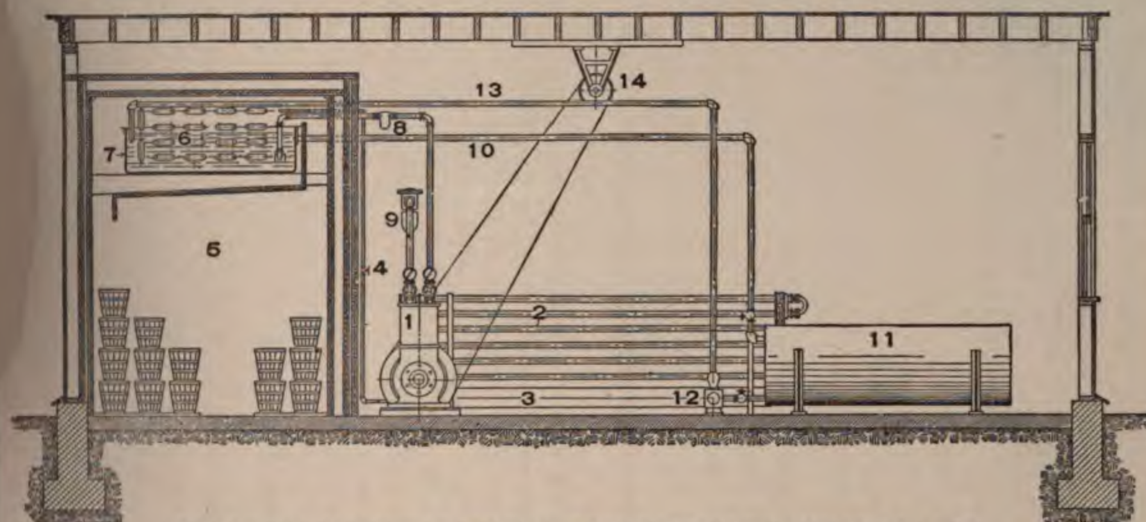


DIAGRAM SHOWING CREAMERY REFRIGERATING PLANT.

1 Ammonia Compressor
2 Ammonia Condenser.
3 Liquid Receiver.
4 Expansion Valve.
5 Cold Storage.
6 Direct Expansion Coil.
7 Brine Tank.
8 Suction Scale Trap.
9 Oil Trap.
10 Brine Line to Cream Vat.
11 Cream Vat.
12 Brine Pump.
13 Brine Return Line.
14 Line Shaft.

What is the condition of butter when first made?

It is then at its best, and the nearer it can be retained in that condition until it reaches the table the better. Therefore it must be kept cool and be hard when it is shipped.

What must be looked out for in butter shipments?

Any temperature below 32 degrees will not harm it, but a high temperature should be avoided.

Is the production of butter increasing?

It is growing rapidly and the quality is improving; probably not more than one half reaches the consumer in as good condition as it should.

On what does the flavor and aroma of butter depend?

It was supposed to be due to the food on which the cattle were fed as the butter was of the best quality in the full grass months of May, June and July, but a culture is now used which gives as fine aroma and flavor in winter.

What is necessary if butter is intended for storage?

The buttermilk should be removed as much as possible without injuring the grain of the butter, and it should be well salted so that the moisture contained in it is in the form of strong brine.

What butter keeps best?

That made by setting the cream in cold water.

How is creamery butter made?

Nearly all by a centrifugal separator.

Does it keep well in store?

Not so well as that made by the gravity process, but it is good for a three to five months' term.

Is it stored in large tubs?

Very often if it is intended to put it in prints, a one pound package wrapped in paraffine paper being a favorite.

Will print butter keep well?

Putting in prints breaks the grain and it will not keep so well It is not so impervious to moisture and air in that form.

What is paste salt which is used as a storage covering?

Salt ground very fine, which when applied readily forms a paste.

Is it desirable to avoid re-packing butter?

Yes, for it breaks the grain and injures its keeping quality.

How is butter best packed in small jars for local trade?

Cover the butter with a parchment or paper cap and put on an eighth of an inch layer of salt, then tie cover of manilla paper over all this, which practically makes an air-tight package.

Jars should be placed on racks, and while they are not adapted for shipping, they are very convenient for local trade.

What packages are most frequently used?

Tubs of white ash holding about sixty pounds.

Why cannot soft woods be used?

These, particularly pine, will give a disagreeable flavor to butter.

How may mould be prevented?

Use brine for soaking the tubs, as it has a tendency to prevent mould.

What is gathered cream butter?

Cream taken from various farmers and made into butter at a creamery.

What is process butter, and how made ?

It is made from a miscellaneous lot of dairy butter melted, purified and flavored by use of a bacteria culture. It is also called renovated butter.

Does it keep well in cold storage ?

No, and very little of it is stored.

When does this processing have an advantage ?

Butter of good quality but which is slightly sour from buttermilk may be restored and improved.

Explain how butter becomes rancid ?

Exposure to the air brings on this condition, the higher the temperature, the more rapidly it takes place.

What follows from this ?

The nearer air-tight a butter package can be, the better.

What is " ladle " butter ?

Butter of good quality but lacking in uniformity of color, salt and package; it is improved by being worked, salted, and packed over again. It does not keep well in store and has been practically superseded by "processing."

What is considered the best temperature for butter ?

While many prefer a temperature of zero, the majority of produce men think any temperature below 20 degrees satisfactory while it is in storage.

Do butterine and oleomargarine keep well in storage ?

They contain so little casein that they keep well for long periods, and at a somewhat higher temperature than butter.

What is the theory of refrigeration relating to cheese ?

It prevents the development of bad flavors and deleterious gases which injure the proper flavor and texture. At the same time it allows the rennet which is used in the manufacture of cheese to fulfill its mission of curing or ripening.

Is cheese good for food when freshly made ?

It is quite unpalatable and possibly unhealthful, and requires curing.

What is the best temperature for curing or ripening cheese ?

Cheese taken directly from the press and stored at a temperature of 45 to 50 degrees.

Should it be placed in cold storage as soon as made ?

There is no doubt that it will result in a much better quality.

Is cheese stored on a large scale ?

Nearly all that is to be kept for future use is put in store.

What is a peculiarity of cheese ?

It improves with age, and will ripen or mature at any temperature at which it may be safely stored. Cold curing and cold storing therefore are practically the same thing.

What special care does cheese require ?

If it becomes too warm the butter fat is started which makes the cheese dry and it disintegrates. If too cold it will freeze and the curd will become dry like sawdust and crumble. It is slow in both freezing and thawing out. A skim milk cheese will suffer damage quicker than a full cream one.

What would be the advantage of shipping cheese to a central point for cold storage ?

The flavor would be improved, the shrinkage reduced to a minimum, and the cheese protected from exposure in warm weather.

What is one of the most profitable branches of the cold storage business?

Furs and fabrics pay better than any other class of goods. The business dates back to 1895.

What precaution must be used in taking in goods?

Some robes and coachmen's garments have a stable odor, other goods are scented with moth balls; they should all be carefully aired before being put in store with other goods.

How should furs be received?

They should be inspected, carefully beaten, dusted and aired before being stored away. Any blemishes or imperfections should be noted on the receipt given at the time of delivery.

How should garments be put away?

On forms or shoulder-stretchers to preserve the shape. If the forms are of metal they should be carefully wrapped to avoid discoloration of light and delicate fabrics.

Should goods be covered?

Yes, and preferably with unbleached sheeting.

What should be done when such goods as furs are taken out of store?

They should be thoroughly aired, until dry, before delivery, otherwise the moisture of the atmosphere may condense on the leather or hide and be erroneously attributed to some fault in storage.

Is ventilation necessary in fur rooms?

It is not absolutely essential, but it is easily accomplished, and a clean sweet-smelling room makes a better impression on prospective customers than one in which the air is close and lifeless.

What is the relation of cold to furs and woolens?

Cold is both instrumental in the original growth of furs, and is as necessary for their preservation. Cold preserves the color and gloss after the furs have been made into garments. Cold prolongs the life of the fur by retaining the natural oils which the dry hot days of summer have a tendency to evaporate, so that not only is the appearance of the fur improved but the softness and flexibility are retained. In short, cold storing is putting the fur back into its natural element. Carpets, rugs and other woolens lose color and life in hot summer air. A cold atmosphere revives the color and freshens the fibers.

The wear and tear of excessive beating is avoided. Garments hung on racks are ready for instant use; may be used for a night and then returned. Curtains and draperies being hung on racks avoid damage from folds. Cold storage gives perfect security from moths.

What is the storage season for furs?

Sometimes six, but usually nine months. Goods carried beyond January 1st are usually charged one-third the long season rate, which carries to April 1st.

What is the proper temperature for furs and woolens?

Forty degrees will prevent the operation of larvæ, but will not destroy them. Probably from 25 to 35 degrees would be a satisfactory temperature if continuously maintained.

What system of circulation is recommended for furs and fabrics?

A forced air circulation with the pipes outside of the room.

What care should be used in storing furs and fabrics?

They should not be stored with goods giving off moisture.

What temperature does the egg of the moth and beetle require for hatching?

Probably over 55 degrees Fahr.

When does the insect damage the fabric ?

In the larval condition, for it is in passing from the egg through this condition into the perfect insect that the larvæ of both moth and beetle eat the fiber of the wool or fur for the grease and animal juice in it. These constitute their principal sources of food, and it is in this way that the larva of the moth obtains its material from which to spin the web of its cocoon.

What temperature was required in a series of experiments to prevent this ?

The movements of the larvæ were suspended and they became dormant below 40 degrees; there was a sluggish movement at 42 degrees; damage began at about 45 degrees and continued to increase until 55 degrees when the larvæ seemed to reach the normal condition of activity.

What has been found to be a safe temperature for protection against the miller and the beetle ?

Forty degrees was proved to be safe although the insects were not killed until 32 degrees was reached, they remaining dormant between 40 and 32 degrees. Even the lowest temperature might not bring about their death for some weeks if they were tightly rolled in goods.

Will a temperature of 32 degrees always kill the larvæ ?

Experiments have shown that sometimes they stand 18 degrees without having their vitality destroyed, but variations, that is high and low degrees successively, seem to lessen their power of resistance.

Why are hops put in cold storage ?

When first harvested they are dried in kilns, packed and sent to market. During the drying process some of the essential oils are driven off and if then stored at ordinary temperatures this process goes on slowly until the hops lose the peculiar

aroma and flavor which constitutes their value. The drying process seems necessary to prevent the hops from becoming crusted and useless but cold storage retards any further volatilization of this oil. The proper temperature is about 25°.

How has mechanical refrigeration been adapted to use in blast furnaces with surprisingly good effect ?

At the Carnegie Steel Co., located at Aetna, Pa., the moisture in the air was long known to affect very greatly the quality as well as the quantity of the iron output. As an experiment the company installed a refrigerating plant consisting of two 225-ton refrigerating machines, and the moisture content removed from the blast by freezing the air amounted to over 10 tons of water per day, which allowed the speed of the blowers to be reduced sufficiently to decrease the power consumption nearly 700 horse-power; this saving more than counterbalanced the power required to operate the refrigerating machines, and, in addition, the iron production rose from 350 to 450 tons per day, with a decrease in the consumption of coke of approximately 350 pounds per ton of iron output. The air consumption was lowered from 40,000 to 34,000 cubic feet per minute, or a decrease of practically 15 per cent.

How are silk cocoons kept in cold storage ?

The hatching can be kept back for about twenty days according to the demands of different nurseries. There is always a demand for the seed reared from those kept in cold storage, as such silk worms are found to be strong and more or less immune from disease.

Why are tobacco and cigars sometimes put in cold storage ?

Fine leaf tobacco is very sensitive, and like hops, loses its flavor and aroma if exposed for any length of time to the atmosphere. An even temperature from 40 to 45° prevents this loss and at the same time guards the tobacco from the attack of insects.

What is to be said about refrigeration on shipboard ?

It is now used not only for the preservation of provisions on passenger steamers and men-of-war, but many steam vessels are fitted for nothing else but the carriage of cargoes of meat, milk, butter, fruit, etc.

How has refrigeration been especially applied to passenger steamers ?

A device for cooling staterooms on vessels fitted with refrigerating machinery is employed. This arrangement consists of a pipe about eight inches in diameter and five feet long, the lower end having oblong openings about four inches deep, so arranged around the bottom as to form a grid for admission of air. Inside the pipe is a brine coil supplied from the refrigerator. On top of the pipe is a small centrifugal fan driven by a motor hung on a bracket to one side. On starting the fan the air is drawn in through the openings at the bottom of the pipe over the brine coil and through the fan back into the room at a reduced temperature. By this device the stateroom is kept comfortable even in sweltering weather, partly due to cooling, but largely to the increased relative humidity.

What causes mould in butchers' meat rooms, also in retailers' meat boxes ?

Lack of circulation, bad location of ice bunker and cooling pipes, improper location of the door, or its frequent opening.

How may this be remedied to some extent ?

The door and cooling surfaces should be so arranged in reference to each other that when the door is opened the warm damp air from the outside will strike the cooling surface in the box and be condensed there, rather than on the side walls or ceiling.

What care should be taken of the box ?

It should be whitewashed, and if it is desired to wash it out quite often it should have a shellac finish.

May vegetables be kept in cellars ?

Yes, although cold storage gives better results. The cellar should have a cement or sand floor and be clean; it should have but few openings to the outside atmosphere and these should have curtains to exclude the light. The temperature should be kept from 35 to 40 degrees. It is difficult to regulate the humidity, which is nearly always a serious drawback.

What is the best method for each vegetable ?

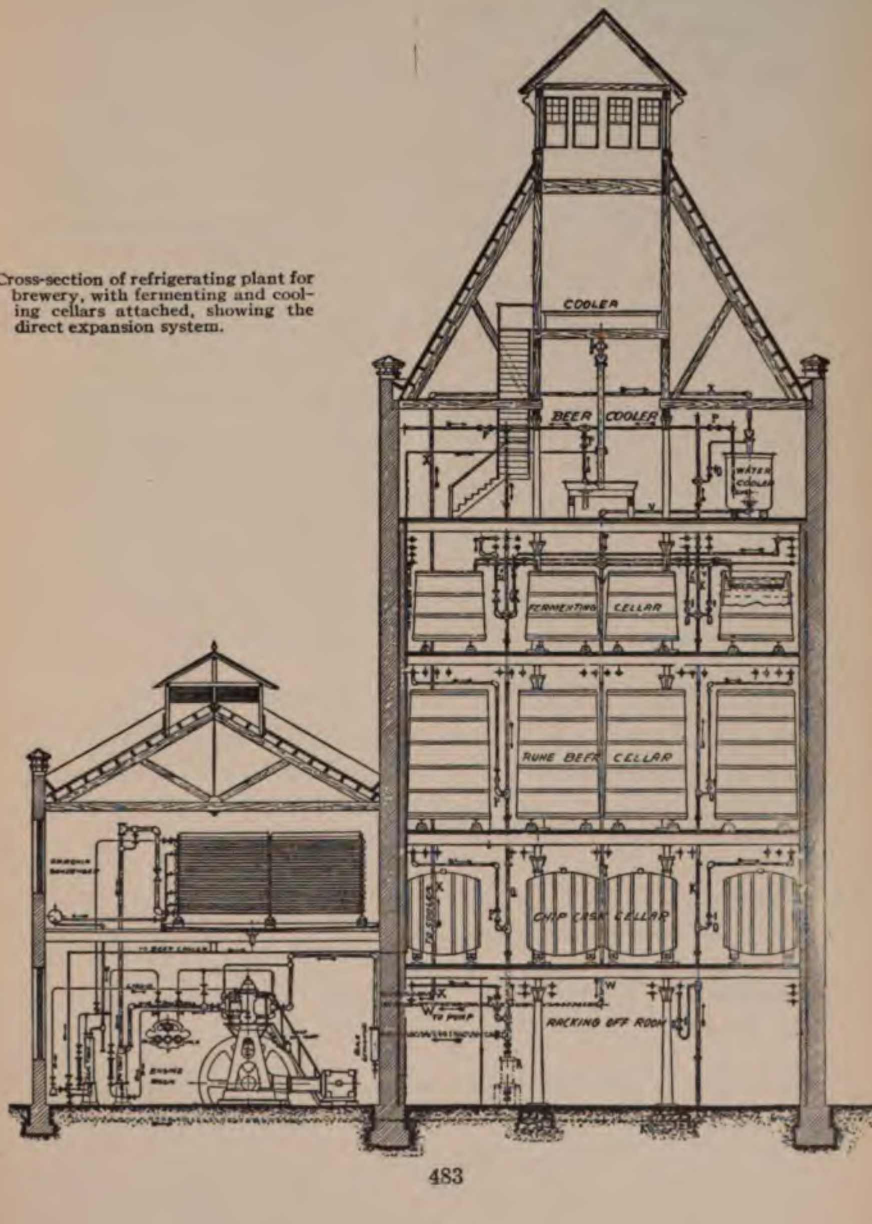
They should be stored in moderate quantities and each kind should be by itself. They should be well matured and gathered before they are chilled or frozen. If picked on a warm day let them cool before placing them in the cellar. Onions and potatoes are best stored on shelves or in bins. Pumpkins and squashes require more air and must be kept dryer than the softer vegetables, like carrots, turnips and beets. Onions keep best without removing the tops. Pumpkins and squashes should be put on a shelf near the top of the room and be inspected frequently. Cabbage may be wrapped in old newspapers and packed in barrels in the coolest part of the cellar. If it is necessary to keep potatoes, beets, carrots, turnips, etc., for late spring use, pack them closely in boxes and barrels, and fill in between and cover with sand or garden soil.

What should be done if the cellar is damp ?

Use a pail or two of lime, which replace when it gets dry and powdery. It will absorb the dampness and unpleasant odors. The cellar should be ventilated by opening the windows from time to time. Too much ventilation during the winter will cause the vegetables to dry and shrivel.

Breaking Bar.

Cross-section of refrigerating plant for brewery, with fermenting and cooling cellars attached, showing the direct expansion system.



What are the uses of refrigeration in a brewery ?

1. To cool the water used in the wort to the temperature of the fermenting tuns (40 degrees).
2. The withdrawal of the heat of the fermenting process.
3. Cooling brine or water for use in the attemperators of the fermenting tubs.
4. Keeping cellars and storerooms from 32 to 38 degrees.
5. For storage and preservation of hops.
6. Cooling of air for malt houses.

How can the refrigeration needed by a brewery be roughly estimated ?

Divide the capacity of the brewery in barrels per day by four; this will give the size of the machine needed in tons.

What is the wort ?

It consists chiefly of saccharine and dextrinous matter dissolved in water; its fermentation produces the beer.

What is the condition of the wort when first made ?

It is boiling hot; it is first run into the cooling vat where it stays for two or three hours, but should not be allowed to fall below 110 degrees; then it flows over the Baudelot coolers for further cooling.

To what temperature is the wort cooled ?

To about 40 degrees for beer or 55 degrees for ale.

How much refrigeration does this require ?

About one ton for forty barrels of wort.

How long does it take to cool the wort ?

Very often the whole refrigerating capacity of the brewery is devoted to it for, say, four hours.

How is the cooling of fermenting rooms and tuns carried on by the carbonic acid machines?

In breweries attention is paid to maintaining air in the fermenting rooms and tuns at a temperature as low as 40 degrees Fahr. to 50 degrees Fahr., to eliminate the risk to which yeast is exposed in a summer atmosphere, even when the wort is attemperated in the most careful manner.

In maintaining a cool atmosphere above the fermentations, the whole of the air in the room may be cooled, or that in the tuns only, if their sides can be raised and their tops covered in. The latter is the most economical arrangement, and has the advantage that the temperature in different tuns may be varied, and the cooling can be stopped entirely in tuns which are out of use. In some instances brine coolers, over which large volumes of filtered air are cooled before being circulated through the rooms, are used. In others, special brine drums, or cylinders, fixed under the ceilings of the fermenting rooms, and through which large quantities of cold brine are circulated, are employed.

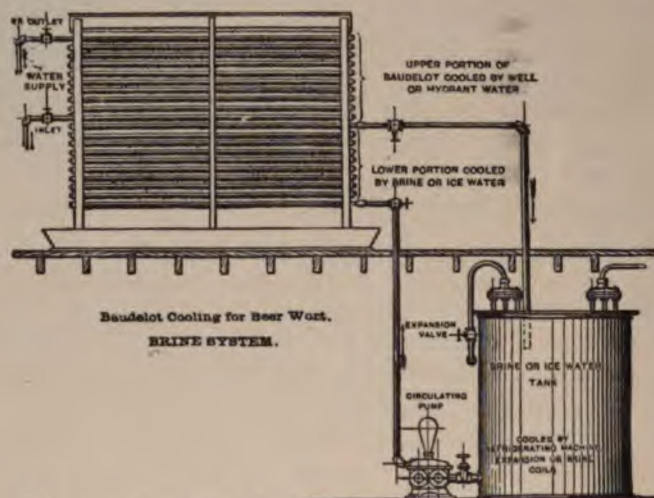
How is yeast cooled in breweries?

The advantage of keeping yeast at a low temperature is now generally appreciated.

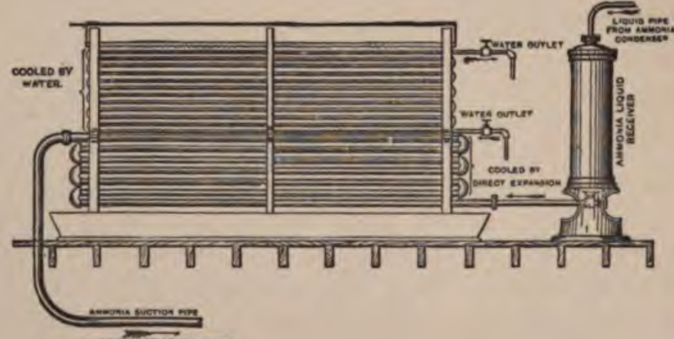
The method of cooling adopted is in some cases by circulation of refrigerated water, or brine, through the false bottoms of the yeast backs, or through coils of piping immersed in the yeast. The latter arrangement necessitates, however, the pipes being removable, to enable them and the backs to be thoroughly cleaned, and, when possible, the yeast backs should be placed in a suitably insulated cold chamber. This system has the great advantage of keeping a cold atmosphere above the yeast.

What takes place in the fermenting tubs?

The cooled malt is "pitched" with yeast and allowed to ferment.



Brine Baudelot Cooler for Beer Wort. Cold water used in upper part.



Baudelot Cooler with direct expansion in lower part.
Cold water used in upper part.

Should the temperature of cooling water be reduced as much as possible in breweries ?

Brewers do not always realize what an enormous quantity of cooling water is used when the temperature at which it is available is very little below that to which the wort has to be cooled, whereas if its temperature is cooled by refrigeration even a few degrees, much pumping is saved, work in the brewery is expedited, and more important still, the wort is got quickly off the "friges" into the fermenting tuns.

How is clear water spoken of in refrigerating plants and breweries ?

As "sweet" water.

If the direct expansion system is used, what must be considered ?

That the ammonia coming from the cellar and the wort cooler are combined before they go into the compressor, as they return with different pressures.

What is the Baudelot Cooler ?

An arrangement of piping used in breweries for cooling the wort, which is boiling hot and must be cooled to the temperature of the fermenting tubs.

How is this cooler sometimes arranged ?

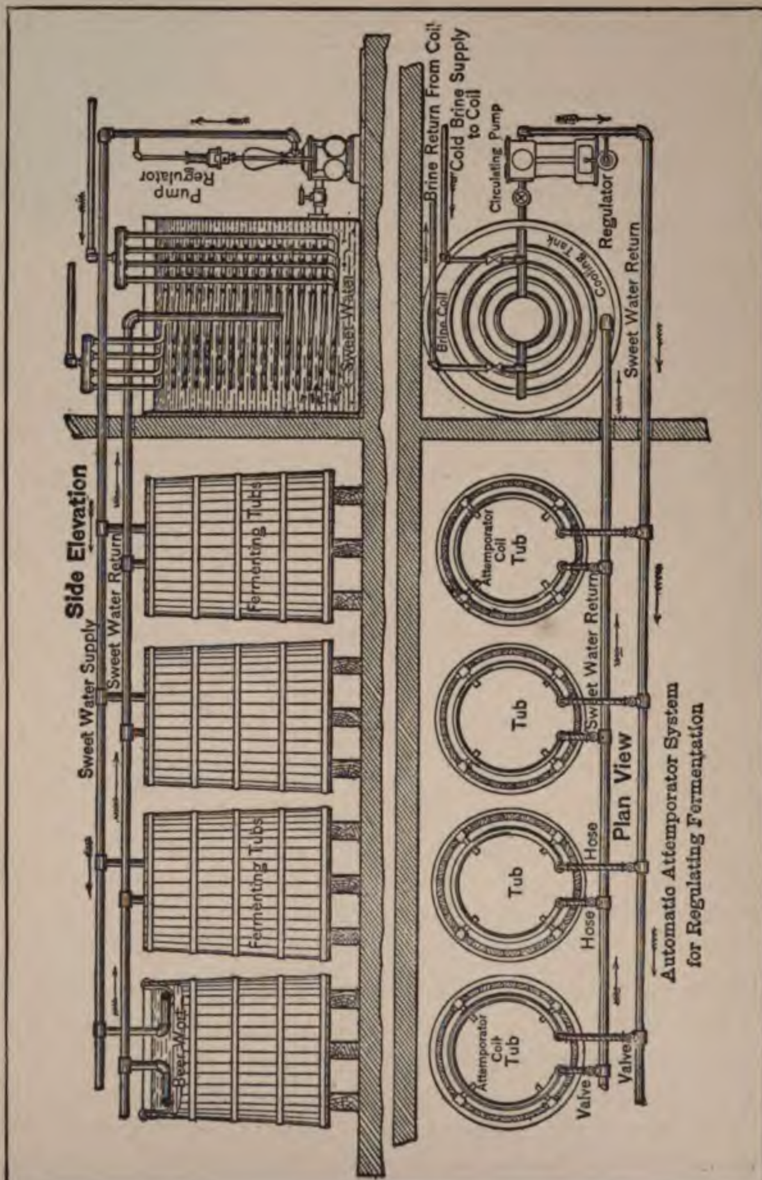
The upper part is cooled by water, the lower by brine or direct expansion.

How does it operate ?

The wort flows over the pipes and the refrigerating medium through them, be it either cold water, brine or a direct expansion system of ammonia.

Which system is the more economical ?

The latter; and as the cooling of the wort is a very important part of brewery work, the expense involved in it has an important bearing on the cost of manufacture.



Automatic Attemporator System
for Regulating Fermentation

How is the temperature regulated in the fermenting tubs ?

By attemperators cooled by water. This is an apparatus for cooling the beer during fermentation. It is a coil of pipe of iron or copper placed in the tub near the top, and is usually hinged so as to be removable.

What is the cooling medium used in this coil ?

Sometimes brine, but usually cold water a few degrees above 32 degrees Fahr.

How is the cooling controlled ?

The amount and pressure of water is regulated by the automatic control of a self-acting pump and regulator.

How is the cooling effected ?

By brine which may be regulated by cutting-out coils as desired, by valves, or by varying the flow of brine.

What back pressure is maintained in breweries and storage warehouses where a temperature of 32 degrees Fahr. is carried by direct expansion ?

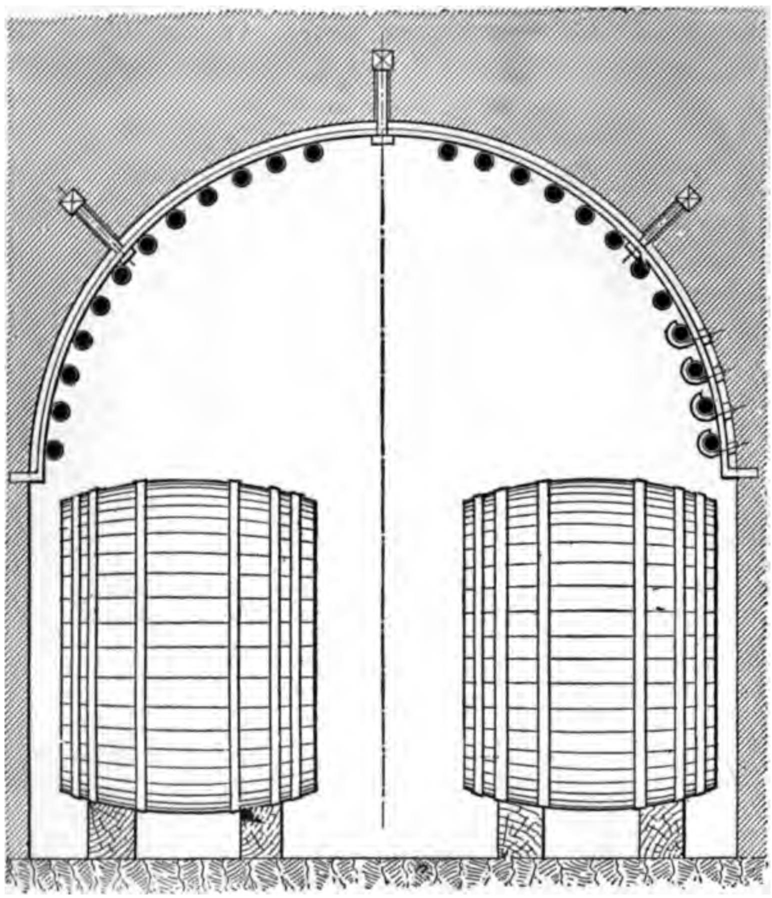
A gauge pressure of about 33 pounds; this corresponds to about 20 degrees Fahr.

How, if brine circulation is used under similar conditions ?

The brine enters the room at about 20 degrees Fahr., and returns at 24 degrees to 26 degrees. The back pressure in the ammonia coils then is 25 to 28 pounds, corresponding to a temperature of 10 degrees to 15 degrees Fahr.

Why is the brine system used with a carbonic acid compressor ?

Because the pressure of carbonic acid is much too great for a direct expansion system, the brine pressure in the pipes being as low as 15 pounds, while the compressor pressure is 500 or 600 at the lowest. Then, too, if the brine system is used, the machinery may be closed down for a time if desired.



Method of suspending expansion or brine piping from an arched ceiling. The curved strip of flat iron is fastened to the masonry by expansion bolts, the pipes being fastened to the strips by straps or hooks as shown on p. 483.

How is the piping located in the fermenting rooms?

It is suspended from the ceiling along the sides of the room and over passageways so that there will be no drip in the tubs, and allowing convenient access to them.

What part of a refrigeration machine usually requires the most attention?

The stuffing box, which must be more carefully packed and closely watched than is the case with steam. (See page 111.)

Does the stuffing box make more trouble on a small machine than on a large one?

No, for the construction is nearly the same; but in the small machine there is less piping and a smaller number of valves; so that if trouble arises it is quite likely to be connected with the stuffing box.

What else must be considered with reference to the stuffing box?

That the small machine generally receives less attention than the large one, also that the stuffing box of the large machine is often adjusted during variations of temperature, but that it is rarely done with a machine of small capacity.

Should the bearings receive attention?

The bearings should be examined for lost motion, etc., at frequent intervals.

Is lost motion liable to cause trouble?

Yes, as the main bearings wear down and the crank pin and wrist pin boxes also wear larger, the shaft drops and the connecting rod shortens. The piston will not come as near the head, at the end of the upstroke as it should, to discharge the full amount of gas, and if such lost motion becomes excessive the capacity of the machine is considerably reduced.

Would lost motion cause any other trouble?

Besides the annoyance due to the noise, the continuous pounding will cause the wear to increase; this will have a tendency to force the lubricant out which still further aggravates the trouble.

Do the valves ever give trouble?

In a small, well-designed machine there is very little trouble experienced with the valves. However, it sometimes happens that a piece of scale from the piping will lodge under the seat of a valve, and prevent it from working properly. In such a case, the temperature in the refrigerator rising rapidly may give a clue to the reason for it.

What should be done if one encounters this difficulty?

(1) The expansion valve should be shut tight; (2) next, the suction stop valve closed; (3) the machine must be turned to the top center; (4) the discharge stop valve be shut tight; (5) then turn the machine completely over and open the discharge stop valve to let the pressure blow off into the condenser, (6) repeat this operation several times.

Why not pump out in the regular way?

If one of the valves is prevented from seating, the machine cannot do effective work and it simply churns a part of the charge forward and back through the imperfectly closed valve.

Is it safe to open the compressor under this condition?

The small amount of gas remaining in the compressor after pumping out in the manner directed may safely be discharged into the room, and the valve can be examined.

What should be done with the valve?

If no damage has been done to the valve or seat, the piece of scale or other foreign matter may be removed. If the valve face and seat are scored the valve will need re-grinding, but if the stem should be bent another valve will have to be inserted, while the damaged one is sent to a machine shop to be repaired.

How is the machine started again?

After the cylinder head has been replaced and all bolts adjusted, the air that has entered the machine while it was open must be removed. To do this, open the purge valve at the top of the compressor and run the machine slowly, with the suction and discharge stop valves closed tight, for about thirty or forty revolutions. Now close the purge valve and open the suction and discharge stop valves; the machine should now be ready to run. The discharge valve must be opened first, if the machine is running, to avoid an overpressure in the valve chambers.

If the suction valve should fail to work effectively, would the above method of pumping the gas out of the cylinder be practicable?

That would depend upon the construction of the machine. A machine with false head and the suction valve located in the piston cannot be pumped out under such circumstances, as the piston stroke would not take hold.

What could be done with a machine with the suction valve in the head?

Close the expansion valve and the discharge stop valve, turn the machine to the top center and close the suction stop valve. If the machine is provided with by-passes, open the one on the discharge valve and allow the gas in this valve chamber to escape into the suction line; as soon as the pressures are equalized close the by-pass, and the gas remaining in the cylinder and valves may then be allowed to escape.

If the bearings become worn, what should be done?

The lost motion should be taken up, but great care should be exercised not to set up the bearings too tight, as this would cause them to heat. In taking up connecting rod boxes, it will be found that provision is made to keep the distance even

from crank pin center to top of piston. In some machines which have a piston rod and cross head, the rod may be unscrewed a fraction of a turn, but here again care must be taken, for if the rod is lengthened out too much the piston will strike the cylinder head.

In packing the stuffing box of a compressor is there any particular point that may cause trouble?

Many stuffing boxes of ammonia compressors are supplied with an oil space between two sets of packing. The oil space is formed by a separator called the lantern, as illustrated on page 114. As the oil is circulated through this lantern by means of pipes leading through the wall of the stuffing box, care must be taken in repacking not to allow the packing or the cylindrical part of the lantern to obstruct the oil passages.

What is considered an advisable packing?

A soft rubber composition, containing a large percentage of graphite.

How should it be applied?

In rings of uniform thickness, with diagonally cut joints. Most manufacturers of compressors recommend a brand of packing which they have found to give the best satisfaction for their machines, and it is well to adhere to the use of same for renewals.

Give some good rules to be observed in packing a stuffing box.

(1) Close the suction stop valve and expansion valve, and run the machine for a few revolutions, and then close the discharge stop valve. (2) Close the oil supply, and remove all the old packing, being careful not to mark the piston rod with the packing hook. (3) Place as many rings in the stuffing box as were removed, and force them tight against the bottom of the box with the lantern. (4) Put in the outer packing, replace the

gland, and set up fairly tight. (5) Now slack off the gland and set it up fairly tight, by hand. (6) Turn on the oil circulation and, with the purge valve open, run the machine for a few revolutions, then close the purge valve and open the discharge stop valve and suction stop valve. (7) If there is any leakage at the stuffing box, take up the gland, but no more than may be necessary to stop the leakage.

Are small machines charged in the same manner as large ones?

The operation is practically the same, and similar precautions must be observed; it is more convenient, however, to use a smaller cylinder or drum of ammonia; one containing about fifty pounds is in common use.

Where is the charging valve ordinarily placed on small machines?

On most machines of low power the charging valve is placed just beyond the expansion valve so that the charging is done on the low pressure side. If the expansion valve is closed the machine will run on the expansion of the liquid from the drum.

What precautions should be observed in attaching the drum to the machine?

Care should be taken that all the connections are tight. The ammonia cylinder should be weighed and compared with its tag, both before and after connection, in order to determine accurately the amount of the charge.

When a cylinder of ammonia is connected to a machine how are the valves opened?

There being two valves between the charge in the cylinder and the circulation system of the machine, some operators open the valve on the machine wide open and, by varying the opening in the valve on the cylinder, practically use that as an expansion valve during the operation of charging. This method is open to the disadvantage that the connections and

machine valve soon frost over to such an extent that the flow may be obstructed, and the machine valve may be injured in the effort to remove the snow and ice from it in order to close it.

Hence it is considered better practice to open the cylinder valve wide and expand the liquid through the machine valve. This confines the expansion effect to the cooling coils, where it should be, and largely obviates any difficulty in regulating the machine valve where trouble is liable to occur if the first method of charging is used.

What should be the position of the drum as the connection is made?

If the drum is of the type shown on page 162 the connection should be made as there shown; the outside valve connection at the top and the internal tube pointing down. On page 173 a different form of ammonia drum is shown and in this type the internal tube points upward. The instructions given in pages 162 to 172 for charging machines are nearly applicable and necessary in the charging of small machines.

Should the compressor be operated during the charging process?

Yes; it should be kept working and water be allowed to flow freely over the condenser.

How can it be told when the drum is empty?

When its contents are nearly exhausted a frost will form on its surface; this will soon disappear, which is the indication that the cylinder is at last empty.

When charging in this way is there any danger of the charge flowing back into the drum?

In this method of charging, where the expansion valve is closed and the compressor is kept running, there is no danger of any liquid anhydrous "backing" into the drum. It is the safest way of charging, and also the most efficient, for the refrigerating value of the anhydrous is fully utilized.

Is the charging valve always placed near the expansion valve?

Some makers place the charging valve on the suction pipe of the compressor. In this case the expansion valve is kept open and the running of the compressor simply transfers the contents of the drum from the low to the high pressure side. This is also a safe method, but the refrigerating value of the charge is not made available.

Is the charging of a small machine ever made on the high pressure side?

Very few machines are intended for receiving the charge on this side. In case it should be necessary to charge against a high pressure no change is made in the adjustment of the expansion valve, but the temperature of the cylinder should be carefully noted and connection *never should be made until the temperature of the cylinder is slightly higher than that of the receiver; this is absolutely necessary in order that the pressure in the cylinder may be greater than that in the machine.*

This and other precautions to be observed in charging machines on the high pressure side (See pages 176 to 179) should always be observed with machines of small capacity, especially the use of a check valve as described on page 178.

Where is the charge removed from a machine either for repairs or laying up?

A valve is usually provided at the lowest point of the liquid receiver, and in installing a machine provision should be made for placing an ammonia drum at a lower level than this blow-off cock.

What other matter should be provided for?

Space should be allowed so that the drum may rest on a scale in order that the drum may not be overcharged, the safe limit of the charge being given on the tag attached to the drum at the ammonia factory.

How is the connection made between the liquid receiver and the drum?

The connection is made as in the charging operation. The position of the drum, however, should be the exact reverse of the illustrations shown on pages 162 and 173.

What is a desirable feature in the connecting pipe?

While it is necessary that the joints should be tight it is well to have it as flexible as possible so as not to interfere with the weighing operations; this is sometimes accomplished by putting one or two loops in the blow-off pipe which provide the necessary "spring."

A rubber hose is sometimes used in which, however, special couplings are necessary, and the tubing should be carefully clamped and tested up to 300 pounds at least.

How is the weighing scale used in charging the drum?

First the empty cylinder is weighed, and to this figure is added the weight of the charge that is to be put in it. The sum of the two figures indicates the notch where the weight is to be placed on the scale beam. When the limit of the charge in the drum has been reached the scale beam will rise, and then the receiver valve and the drum valve should both be closed immediately.

What should be done if any leakage is noticed in the connections during this operation?

Close the valves and try to repair the leak by "tightening up;" if this is impracticable a piece of soft sheet rubber may be tied over the leaky joint, or a small leak may even be covered with a wet sponge for a time.

What becomes of any ammonia that may be left in the connections?

The shorter the connection can be made, after providing for convenience and flexibility, the better, as some ammonia will remain in it after the valves are closed.

This remnant must be allowed to escape into the atmosphere; the danger and annoyance may be reduced by having a large wet sponge ready to be laid on the joints as soon as they are broken. If a stream of water from a hose is at hand to play on this sponge it is so much the better.

What is an advantage in the use of a rubber hose?

If of sufficient length it will allow the drum when filled to be placed on end, the liquid in the hose will then expand into the gas space of the drum and thus reduce the amount of waste.

What should be done when no more ammonia can be drawn from the liquid receiver?

The plant should be pumped out in order to exhaust the ammonia from the coils.

Describe this operation.

The liquid receiver is generally supplied with a stop valve located at the highest point in the pipe leading to the expansion valve. This stop valve should be closed tight, but the expansion valve, as well as all valves between the expansion coil and the compressor and between the compressor and liquid receiver, should be opened wide.

The compressor should be kept running and water should flow over the condenser as usual.

How long should the compressor be kept running?

When as low a vacuum as possible has been pumped on the low pressure side the compressor should be stopped, but the water should not be shut off the condenser until a few minutes later. The gauge on the low pressure side must be closely watched and if it goes up, the compressor should be started again, and the operation repeated if necessary, until the low pressure gauge remains stationary, which is a sign that the liquid ammonia gas has been exhausted from the piping and coils.

What is the conclusion of the operation?

As has been stated, the condensing water is allowed to flow for a short time after the compressor has stopped working which is necessary in order to condense the last of the gas which has passed through the compressor. Five or ten minutes will probably be long enough for this final condensation, when the water may be shut off and the liquid drawn off from the liquid receiver as before. (See diagram of charging and discharging operation on page 168).

Will some gas still remain in the machine?

The gas which remains in the high pressure piping and coils cannot be reclaimed except at very high pressure or low condenser temperature, and therefore will have to be blown off into the atmosphere.

How can one tell, when a valve is out of order whether it is the suction or discharge valve?

(1) By closing the suction stop valve, turning the machine over by hand, and noticing how much force is required to carry it over the top center. (2) Now, open the suction stop valve and repeat the operation. If the force required is practically the same in both cases it shows that the suction inlet valve is tight. If the suction inlet valve had leaked, the charge in the cylinder would have been forced back into the low pressure side and less power would have been required in the second case than the first to operate it.

How should care be taken in breaking ammonia joints?

As ammonia joints are usually flange joints, after pumping out, the bolts should all be slightly loosened so that the flange can be pried apart; if there is any ammonia in the coils its escape can thus be regulated, for the bolts are all still in position, which would not be the case if they had been taken out before the joint was opened. (See pages 82 and 590.)

GOODS STORAGE.

The storage and artificial preservation of various kinds of products soon bids fair to be one of the world's greatest industries; it embraces both the economy and the comfort of millions of people.

What is the most profitable commodity in the cold storage business?

Eggs in packages are the largest and best paying.

How long are they usually kept in storage?

From six to eight months.

About when are they usually stored?

In April and early May, and they seldom stay longer than the following February.

How are eggs assorted?

Eggs should be selected and imperfect ones picked out by the process called "candling." As they will absorb odors care should be taken that they are not stored with anything likely to thus affect them.

Should eggs be washed before being stored?

No, as it makes the shell dead and lusterless.

How are eggs shipped?

They are packed in crates with separate pasteboard divisions, and excelsior above and below. They cannot stand a temperature of 28 degrees, but if well packed, and they are not delayed on the road, they may pass through a lower temperature without harm.

How can eggs be shipped in winter ?

If they are taken direct from store and loaded into a refrigerator car at 30 degrees or less, and are on the road with the outside temperature at zero, they will freeze, but if started at a temperature of 45 to 50 degrees moderate protection in a good refrigerator car will answer, and they will go through safely.

What care should be taken of the rooms used for egg storage ?

They must be kept clean, and well painted or whitewashed when not in use. The moisture should correspond to the temperature; that is, from 80 to 60% as indicated by the psychrometer for temperatures from 30 to 40 degrees Fahr.

How may eggs be damaged by too close piling ?

They will be damaged by piling them solid. They should have strips between the tiers and open spaces at the ends and sides.

What temperature is best for eggs ?

The American practice is 30 to 40 degrees, but English packers prefer 40 to 45 degrees.

How low temperature will eggs stand without freezing ?

As low as 28 degrees Fahr.

Does the proper humidity for cold storage goods vary with the temperature ?

It does; it is particularly important in the case of eggs.

How are they stored in bulk ?

The contents are taken out of the shells and put in tin storage cans containing about fifty pounds. Bulk eggs may be kept indefinitely about 30 degrees, but must be used soon after thawing.

How is it necessary to first treat the eggs when canning them ?

The yolks must be broken or they will become solid as if cooked. The semi-liquid when removed from the shell should be scraped, by the use of a wooden paddle or scraper, through a galvanized wire screen of one-half or five-eighth inch mesh and caught in a shallow pan; passing through the screen will break the yolks. Before putting in the permanent storage package the egg meat should be thoroughly stirred from the bottom as the yolk is lighter than the white and has a tendency to remain on top; careful stirring will mix them thoroughly.

How are the two parts of the eggs divided if to be frozen separately ?

The white will run a little ahead of the yolk, so it is better to let some of the white go along with the yolks, for they will thaw out more smoothly and they sell better if even. The whites also should command a higher price if sold separately.

How are bulk eggs at first treated ?

As soon as taken from the shell the bulk eggs should be placed in a cool room; if they are prepared in a storage house they should be removed to the freezing room every hour; if made ready at a distance, put them in a refrigerator at least every night.

How are bulk eggs frozen ?

Fill the tin can two-thirds full and freeze; then fill to within one inch or one-half inch of the top and freeze again. This will avoid a large hump in the center which may come if the full pail is frozen at once. Then solder, if it is the intention to seal it. If in an ordinary package, and the yolks and whites are separate, or even if all are to be frozen together, put half an inch of the whites over the top and freeze; then put a parchment paper circle over all, fastening it down with the egg white.

What is the object of the parchment paper circle ?

It tends to prevent the formation of the leathery skin on the top.

How are eggs preserved in bulk ?

The package should be hermetically sealed. Tin is better than glass or crockery, but the tin should be of good quality or it may rust and discolor the contents of the storage cans.

How are the cans next treated ?

Some packers pump the air out before soldering the packages, but equally good results may be obtained by soldering tight after the egg meat is frozen, as the air in the tin contains little moisture it having been already partly sterilized by the low temperature of the room.

Is soldering necessary ?

Yes, it makes the package easier to handle and prevents the formation of a tough leathery skin on the surface of the egg meat.

What is the profitable temperature for freezing and storing eggs in bulk ?

If they are separated and frozen at 20 degrees Fahr. they can be used like perfectly fresh eggs.

What should be done when bulk eggs are taken out of cold storage ?

Thaw out the contents of the can by putting it in cold water. This is much better than thawing in a warm room. They should be used as soon as they are thawed.

How may the age of eggs be approximately determined ?

By putting them in a solution of two ounces of salt in a pint of water; a fresh egg will sink to the bottom; one twenty-four hours old will sink below the surface only; one three days old will swim, and if older than three days it will float on the surface.

The older the egg, the higher it will float, one two weeks old having very little of the shell below the surface. These changes are due to the decrease in density of the egg due to loss of moisture.

What is required in small storage plants ?

Fruit and vegetables require a higher temperature than cheese, and butter needs a lower one. Butter and cheese, too, are liable to take up odors, hence the storage of miscellaneous goods is to be avoided as much as possible unless for brief periods and when the ventilation is good.

What classes of goods may be stored together ?

Fruit, vegetables, dry fruits, nuts, flour, etc., may be stored together at a temperature of 45 degrees down to 35 degrees.

What are the usual cold storage temperatures ?

Few products are stored above 32 to 34 degrees, and a large share of the business is done from 30 to 32 degrees.

How can these temperatures be reached ?

Only by two methods: First, ice and salt or calcium; or, second, by use of refrigerating machinery.

What are other cold storage temperatures ?

For chilling about 30 degrees, for freezing from 10 degrees Fahr. to zero. In general about 34 degrees.

Why do temperatures vary in practical management ?

The temperatures should differ not only with the class of goods, but they should be changed to agree with the previous handling and final destination of the goods; also with the quality, and whether they should be frozen or cooled.

Why are the tables of cold storage temperatures arbitrary to a considerable extent ?

Because the refrigeration depends very largely on the quality of the goods, the length of time they are to be in store, conditions of air circulation, humidity, etc.

Can goods be frozen without damage ?

Many classes of goods can be, if care be used in thawing out.

Can temperature tables be closely followed ?

Only approximately, for one must be largely guided by previous experience, study of conditions, and good judgment.

Is there any basis for the belief that if goods are frozen quickly and thawed slowly when taken out, the original flavor and aroma will be better preserved ?

There is little or no basis for it

How should goods be packed while in store ?

They should be piled or stacked so as to be under the best possible conditions and take up as little room as may be consistent with keeping them in good condition. The warehouse foreman will probably take the precaution that no more work is required than is necessary in getting them in or out.

What classes of goods may be closely piled ?

Butter, canned or dried fruit, for these goods do not give off moisture.

How may they be injured in piling ?

They may be piled so closely that the air will not circulate, or so high that the lower tiers will be crushed.

How about goods that are frozen ?

Those like fish, poultry, etc., should be kept from contact with air as much as possible.

On a rough estimate, how much space will the usual classes of goods occupy ?

60 pound tub of butter	2½ cubic feet
Case of eggs, 30 doz	3 cubic feet
60 pound box of cheese	2 cubic feet
3 bu. bbl. of apples	8 to 10 cubic feet

How is space calculated for each lot ?

Multiply the number of packages by the figures given on page 506, and add 15 to 25 per cent for passages and ventilation.

How may danger of sweating be prevented ?

This is often caused by the condensation of the moisture of the warmer outer air when goods are taken out. If due notice can be had it is better to have the goods removed to the delivery floor and covered with a tarpaulin or heavy canvas so that they will warm gradually. In comparatively cool weather, if they are removed this way at night, they will be ready for delivery in the morning. In the summer 36 to 48 hours may be necessary. This method is particularly desirable in the case of eggs, for slowly raising the temperature aids materially in their preservation and greatly improves and facilitates the work of candling.

How should poultry be treated upon arrival at receiving centers ?

It is necessary to freeze it quickly because it has often been from one to two weeks killed. In freezing poultry it is best to cool it down to 40 degrees before putting it in permanent storage packages. It is best to wrap each bird in paper and pack in flat boxes. These should be placed on edge in the freezing room and on strips on the floor, and a space of three to six inches between the boxes; this allows a circulation of air and rapid freezing. When thoroughly frozen they may be piled up solidly, but with strips beneath, and space between the piles and the walls.

What can you say of temperature for poultry ?

For temporary holding without freezing 30 degrees.

If freshly killed and in small packages 12 degrees to 15 degrees. A month or six weeks is the limit for the higher rate.

How is poultry shipped ?

If the temperature is over 50 degrees it should be packed in ice and burlaps.

Can potatoes be profitably kept in cold storage ?

As they are stored only during cold weather the cost is small. If kept in cellars they sprout in mild weather and freeze quickly at 32 degrees; light should be excluded from the storage room.

At what temperature may potatoes be stored ?

If kept about 34 degrees they will go through the winter in fine condition.

How about cabbages ?

They may be carried some time in a green condition at about 34 degrees. Freezing will not damage them if they are thawed out slowly.

How are fish treated ?

They are kept for twenty-four hours in the sharp freezer 16 degrees below zero; they may then be kept in one 18 degrees above. Oysters should not be frozen but may be kept at 40 degrees Fahr.

How are fish shipped by railroad cars ?

Both by express and freight. In the former case they are packed in ice in small packages, but in the latter in 600 pound casks, or thereabouts, or with ice in large boxes on wheels which hold as much as 1000 pounds; the allowance of ice is half the weight of the fish. Fish may be thus kept for three or four weeks. The entrails should be removed, especially if the fish are to be shipped long distances.

Are beer, wines, etc., stored at the temperature at which they go into consumption ?

They are stored between 33 and 45 degrees. Beer, ale and porter should not be drunk under 52 degrees; 57 to 61 degrees are preferable temperatures.

What precaution is necessary in railway car service?

Excessive cold in winter must be looked out for, also a high temperature in summer. It is desirable to have the temperature as uniform as possible at all seasons.

What is necessary to provide in shipping perishable freight?

Not only protection from excessive heat and cold, but some form of ventilation.

How are cars often warmed?

Sometimes by steam from the locomotive, also by stoves.

What precautions should be taken against cold?

Packing in paper, straw or sawdust, boxing, barreling with paper lining, shipping in paper-lined cars, refrigerator cars and cars heated by steam, stoves, and salamanders. It often depends on the goods, their condition when shipped, how long they will be on the road, whether the car will be in motion constantly, and whether the car will stand on the track for any length of time. The direction of shipment, whether to or from a cold area, should also be considered.

Can the danger from cold be successfully met?

Yes, the lined car suffices in spring and autumn, and special cars used in very cold weather meet the question how to avoid the danger.

What are lined cars?

Cars lined with grooved and tongued boards. They are satisfactory for shipping potatoes, if warmed by a stove, even when it is 20 degrees below zero outside.

What is a very good arrangement for potatoes?

A false floor and a partial false ceiling in addition to the lining, thus allowing a good circulation of warm air.

Is there any difference in refrigerator cars ?

Yes, in some of them a temperature of zero outside is dangerous, the better class will carry goods through safely if even as low as - 20 degrees outside if this temperature does not last longer than three or four days.

What must be borne in mind in shipping perishable goods from the Pacific to the Mississippi river or Atlantic coast.

That the car has to pass through several variations of climate whatever may be the time of the year.

How are products packed if sent loose in a car ?

Straw or mill shavings are largely used.

Does the previous temperature of the goods need to be considered ?

If the produce has for some time been exposed to a low temperature this matter should be taken into account, for it is not so well fitted to stand cold.

Will a low temperature injure foods forwarded in cans or glass ?

Considerable risk is incurred in shipping any long distance.

How should care be taken in fruit shipments ?

The fruit should be cooled down, to, say, 40 degrees, and kept in the car from 40 degrees to 50 degrees. The most important thing is to have the temperature uniform, in which case the fruit may be kept twenty to thirty days. If fruit is intended for immediate shipment it should be gathered in the cool hours of the day. If fruit is warm when shipped it may deteriorate seriously in a short time. The best informed fruit growers in the south have come to the conclusion that it is not good policy to ship peaches and melons direct from the orchard.

What is the usual custom in shipping lemons and oranges from Florida ?

Oranges are shipped to Minnesota in ventilator cars as far as Nashville, where they are put in air-tight refrigerator cars to des-

tination. If the temperature remains above 32 degrees, however, the ventilators of the refrigerator cars are kept open between Nashville and St. Louis. Oranges and lemons are packed in crates and protected by straw. Both require opening or closing of the ventilators as the temperature rises or falls.

What must be considered in shipping fruit?

It depends upon whether it is a refrigerator or ordinary freight car, whether lined or not, whether standing still or in motion, and also on the weather, whether windy or calm, warm or cold. If heated, a refrigerator car can be kept at any desired temperature.

How are bananas shipped in small lots or single car loads?

Bananas should be put in paper and then in thick canvas bags. They are very susceptible to cold and require great care. At 45 degrees they will chill and turn black. In carload shipments in winter a refrigerator car is heated by oil stoves to 90 degrees, then the fruit is quickly loaded and the temperature again run up to 85 or 90, when the car is shut tight and the contents are safe for 48 or 60 hours. A man is frequently put in charge to open and close the ventilators.

How are quinces, apples and pears shipped?

Nearly always in barrels.

Is straw necessary between the packages?

It is only needed on the top, bottom, ends and sides of the car.

How are early vegetables shipped from the south?

Where the journey will take over forty-eight hours they are sent in boxes or barrels with openings cut for ventilation. Ordinarily, the owners will not ship if the temperature is as low as 20 degrees, and not at 32 degrees if it is snowing or raining.

Is it wrong to overload a refrigerator car?

Yes, 12 to 18 inches of space should be left at the top of the car, and space should be left between the packages also. If the car be packed too full warm air from the fruit will collect at the top of the car, and no refrigerator car will maintain a uniform temperature under those conditions. Pacific coast fruit shippers have learned this fact and nail strips of wood between packages which holds them in place and affords ventilation.

Are tables of highest and lowest temperatures safe for goods, necessarily approximate?

They are, because: 1, the initial temperature of the goods when loaded into the car; 2, temperature; and, 3, time they are on the road, must all be taken into consideration. Ripeness and kind of fruit must also be considered.

What temperature is maintained in meat shipments?

36 degrees to 40 degrees is considered satisfactory.

How is fresh beef shipped?

It should be chilled to 36 and the car should be at the same figure. It is desirable that the temperature be kept as even as possible from the chill room at the shipping point to the chill room at the point of destination.

How are meat shipments cared for in winter?

Stoves or oil lamps are used to keep the temperature about 36 degrees.

Can meat be shipped in ordinary cars?

If meat has been thoroughly cooled it may be kept several days in a box car if it is wrapped in burlaps and hung up so that the carcasses do not touch one another. That is if the outside temperature is not above 50 degrees.

What is the custom in case of meat refrigeration ?

In the chilling stage, the temperature of the room may rise to 50 degrees, and a back pressure, about 60 pounds, corresponding to a temperature of about 40 degrees Fahr. in the ammonia coil, is maintained.

The temperature falls gradually and finally reaches the point corresponding to the temperature of the room for cold storage; that is, about thirty pounds back pressure. In freezing meat, temperatures as low as zero are required, and the back pressure falls as low as four pounds corresponding to a temperature of -20 degrees Fahr.

How is the animal heat taken out of a meat carcass ?

It may be carried through a chilling room or rooms by slowly moving gearing until it arrives in the storage or shipping room properly cooled.

How long must meat be kept in cold store to be palatable ?

Two weeks; it may be kept from three to four weeks in an ordinary refrigerator at 40 degrees.

How should meat be frozen and why ?

Very gradually, so as to avoid rupture of the cells; there should also be a good air circulation.

How should defrosting of meat be done ?

As gradually as it was frozen.

How is meat usually shipped by steamer ?

It is usually frozen, to provide against accident, otherwise 32 to 35 degrees would be low enough.

Does pork require special care ?

Great care should be taken in storing and shipping; a high temperature affects it more rapidly than other meats.

What must be considered in the storage of lemons?

Lemons require a temperature from 35 degrees to 40 degrees; they are very sensitive to cold and might be seriously damaged if the temperature should fall to the freezing point. Thirty-eight degrees is recommended.

What temperature do oranges require?

Thirty-four to thirty-five degrees.

Does the aroma of lemons and oranges affect eggs and butter?

The flavor of citrus fruits affects them greatly, and they should not be stored anywhere near together, certainly not in the same room.

Why must care be taken of citrus fruits?

Oranges and lemons, after being in storage for some time, give off a gas which is very penetrating, and they should not be in the same building with eggs.

What course is recommended?

At least that a separate entrance be provided if it is necessary to use a room in the main building.

Why do these fruits require great care?

If the atmosphere is very dry, they shrivel up and tend to decay quickly. If the air is too moist they mould and become musty. There is more danger from the latter than the former condition and the damage is greater. The best temperature is about 35 degrees to 40 degrees, with the moisture carefully regulated; a forced circulation is beneficial.

What is of great importance in connection with cold storage in general?

The condition in which goods pass from cold storage into consumption is only second in importance to the storage itself.

What commodity is second in importance to eggs in the cold storage business?

Butter.

What is the most desirable temperature for butter?

There is a difference of opinion, some keeping it in practice from zero to 10 degrees Fahr., while others think from 12 to 15 degrees Fahr. low enough.

How about humidity?

The room should be kept only dry enough to prevent the formation of mould. If the room is too dry it affects both the packages and the butter.

How is butter kept in cold storage?

By freezing at from 5 to 10 degrees and then keeping at 15 degrees. It may also be kept at ordinary cold storage temperatures; the lower temperature is better, however.

What is the effect upon butter of freezing?

When it thaws out very gradually the flavor is improved.

Does butter really freeze?

Butter fat does not freeze, but as the temperature falls it grows harder and harder.

How about the necessity for slowly cooling?

Butter in many cases is kept at zero, but it would be better for the goods and more economical for the warehouseman to bring the temperature down gradually, say in a 25 degree to 35 degree room before running it into the freezer. It would also be easier to carry an even temperature in the freezer if it was not suddenly called upon to take up such an amount of heat all at once.

Should butter be kept beyond the selling season ?

It is liable to deteriorate if held over six or eight months, even if kept at zero.

Is ventilation of a butter room quite necessary ?

Yes, butter should always be protected from the air.

What facts should be kept in mind in putting cheese in storage ?

It is usually put in storage in mid-summer and taken out in mid-winter, hence it should be well advanced in ripening. It should be kept from freezing and may be a year in storage if it is necessary so to do.

At what temperature is cheese stored ?

The best temperature is 32 degrees to 33 degrees, and it should be maintained very evenly. The humidity of the room should keep the cheese from shrinking or cracking but it should not be so great as to make mould on the cheese.

How about the humidity required by cheese in storage ?

Cheese requires about the same humidity as eggs.

How early in the cheese manufacture can it be stored ?

Very often it is stored when only eight or ten days old and before it is properly "cured;" then the temperature should not be lower than 38 degrees. Afterward the temperature can be gradually lowered until in three or four months it may be brought down to 30 degrees; it should not go below that, and even there, if kept for any length of time, it may make the cheese "short" or brittle in texture.

What is necessary to bear in mind regarding cheese ?

That there are many makes and qualities; the above remarks referring to the average make of American Cheddar cheese.

What are the main classes of goods to be found in the holding freezer?

Butter at zero, poultry, meat, fish, and frozen eggs at 10 degrees above.

What are found in the sharp freezer?

The same goods, with the exception of meat, and with a temperature of, say, from 5 to 10 degrees below.

What is the usual capacity of egg and fruit storehouses?

About 50,000 cubic feet, sometimes 70,000, for houses commonly located at stations in country towns.

What for sharp freezing?

About 10,000 to 15,000 cubic feet.

What is said of the storage of ferns?

It is quite an important industry in some parts of New England. They are picked after the first frost as they are tougher and will then better stand handling and transportation. They are sorted, tied in bundles, packed in wooden boxes and slightly moistened. They are then shipped to cold storage warehouses, and any temperature below 32 degrees that will stiffen the ferns so that they are frozen will keep them as long as may be desired. Ferns are in demand all through the year and especially during the holiday season.

Can peaches and strawberries be stored to advantage?

The softer juicy fruits will not keep for any length of time in cold storage, and it should not be resorted to except to carry over for a few days during a glut in the market.

What is the limit of the ice refrigerator?

Only for temporary storage, and it should not be used otherwise.

In the refrigeration season, what goods do apples take the place of ?

In many cases as the eggs go out in the fall they are replaced by apples.

Could they be stored together ?

No, and after the apples go out the rooms should be whitewashed before eggs are taken in.

How may uniform color in apples be secured ?

1, by pruning, to let the sunlight into the tree; 2, by cultural conditions that will check the growth of the tree early in the fall; and, 3, by picking over the tree several times, taking only the best fruit each time.

Define apple " scald."

When the apple reaches a certain degree of ripeness, that part of the skin which was grown in the shade sometimes turns brown, this part gives the name of "scald."

Why is this objectionable ?

While it does not harm the fruit, it affects its appearance and reduces its value.

Where does the scald first appear ?

On the green or less mature side.

When is the fruit most susceptible to scald ?

When it is picked before maturity; it may come from the picking of fruit when too green, dense-headed trees that shut out the sunlight, heavy soil, or a location or season that causes the fruit to mature later than usual.

Does the scald have a tendency to appear as ripening progresses ?

It does, and the owner should aim to remove them from store and dispose of them for consumption, before it makes its appearance.

What are desirable qualities in the apple ?

To be fully grown and highly colored when picked; then it is less liable to scald, and has the highest commercial value.

Does delay in sending apples to store have a tendency to promote scald if the weather is warm ?

Warm weather would have a tendency to hasten ripening and there would be danger both from scald and rotting.

Does wrapping the apple retard the scald ?

It seems to make very little difference; however, the paraffine or wax paper is the best for the purpose.

Is a wrapper of value ?

It is of advantage in preventing the transfer of fungous growth and besides, the wrapper retards the ripening processes.

What is thought to be the best wrapper for apples ?

A porous white paper put next to the fruit and a paraffine wrapper over it.

What is the size and cost of this wrapping ?

Say, 9 x 12, costing 20 cents per thousand for the white paper, and about 70 cents for the paraffine. The white paper should be of the weight and quality of newspaper before it is printed.

What are other advantages of the wrapper ?

It checks transpiration of moisture, and lessens wilting, protects from bruising, and prevents the spread of fungous places. A wrapper should always be used on the best grades.

What is the effect of picking an apple ?

The removal from the tree stops its growth and brings on its ripening; this is hastened by a high temperature and retarded by a low one.

What is liable to happen if they become heated soon after being picked ?

Fungous diseases develop, such as apple scab, pink mould, blue mould, brown, black and bitter rot, etc.

Is careful handling of fruit very important ?

Yes, a bruised spot dies and discolors; again, careless packing and handling are sure to make trouble if the goods are to be kept any length of time.

When do apples tend to break down and why ?

Late in the spring, as they then become far advanced in their life and tend to break down whether in store or not.

What are the principal packages used for apple storage ?

Barrels holding about three bushels and boxes containing forty to fifty pounds.

Do the packages need to be ventilated ?

There is considerable difference of opinion as to the value of ventilated packages.

What may be the effect if there is too much exposure ?

The apples may grow corky or spongy.

What may happen when the fruit grows mellow ?

Apples in barrels may bruise by their own weight; this is less likely to happen if they are packed in boxes.

What must be taken into consideration in storing apples ?

The condition in which they will come out is affected by their stage of ripeness when stored; also, how they have been grown or handled.

Cold storage will retard the development of the diseases with which the fruit is affected but it cannot prevent the slow growth of some of them.

How should apples be packed in a storage warehouse ?

The barrels should be on end and a 2 x 4 strip between each tier of barrels, so that the weight will be supported by the heads of the barrels and not by the center or bilge.

What advantage have small packages, in fruit storage ?

The fruit cools down more quickly and this checks the ripening. In large packages, like a barrel, the fruit in the center cools down more slowly than that on the outside.

When is the end of the apple storage season ?

Early in May.

What is considered the proper storage temperature for apples ?

For long-period storage of the better keeping varieties, with proper air circulation, 29 to 30 degrees. They should be cooled down slowly, say two or three weeks, from 60 or 70 to 29 or 30.

If accidentally slightly frosted they are not necessarily injured if they are thawed out slowly.

Does the distance to be shipped make any difference in the storage temperature ?

If placed in store near where they are picked, 34 to 35 degrees may be satisfactory, but if shipped to some commercial center, 32 degrees may be necessary to overcome the abuses of picking, packing and shipping.

Is there any difference between the temperatures required for sour and sweet fruit ?

Yes, sour fruit will not stand as low a temperature as sweet fruit.

If fruit spoils at a temperature below 40 degrees, to what is it usually due ?

Very largely to moisture.

How are apples liable to be frozen ?

If the storage plant is not managed properly, they may be placed too near the circulation pipes or the cold air duct.

Do cold storage apples tend to deteriorate more rapidly when taken out than if they had not been stored ?

If they are over-ripe, and many of them are kept in storage until they are, they may break down quickly, but firm stock may be kept even months after being taken from store.

What are the actual facts regarding this subject ?

If the temperature of most perishable goods be reduced gradually when they are placed in store, and raised gradually when they are ready to come out, they will have nearly the same vitality for rough usage as if they had never been in store. Sudden changes in temperature should be avoided.

What is the most that can be expected from cold storage of apples ?

The cold storage may retard but will not prevent their decay; the character of the soil, the altitude, the orchard management, the picking, packing and shipping, are all factors that must be taken into account.

Does cold storage improve the grade of any class of goods ?

No, only the best selected stock should be put in store.

Does it seem to produce scald more quickly if the apples are allowed to rise rapidly in temperature ?

It does, and the humidity of the air when the apples are taken from store also has an effect on it.

Where is there still a field for investigation in fruit storage ?

The question of temperature has received much study, but the air circulation, ventilation and humidity also require careful attention.

Where is the greatest development of the fish freezing industry ?

Along the great lakes where several million pounds of white fish, trout, herring and pike are frozen yearly. On the Atlantic coast bluefish, squeteague or weakfish, mackerel, smelt, sturgeon, herring, etc., are frozen. On the Pacific coast large quantities of salmon and sturgeon are frozen and shipped to various parts of the world.

What is the state of this industry in Europe ?

Hamburg and other continental ports import several million pounds of frozen salmon yearly, but while they use refrigerating machinery for preserving beef, mutton, etc., there is comparatively little fish freezing done.

What is found necessary in fish preservation ?

By the use of ice, only, the temperature of a fish storage room cannot be kept below 36 degrees during the summer, and the fish lose flavor, and eventually spoil, hence it has been found that the fish must be frozen as soon as possible, and then kept at a temperature below freezing.

Is it true that freezing destroys the flavor of fish ?

This very general belief is not well founded, the result depending more on the condition of the fish when cold is applied, and the manner of such application, than the effect of freezing.

How does freezing affect the value of fish as compared with meat ?

Fish loses less in value from freezing than meat does, but it is subject to two difficulties from which meat is free: 1, the eye dries up, and, 2, the skin becomes hard and loose on the flesh, but frozen fish is not less wholesome than fish not preserved.

Why is objection raised to this form of food preservation ?

That there is a tendency to freeze fish which are slightly tainted. This is where the trouble begins.

Is there any question as to the value of freezing if the fish are in proper condition ?

If in good condition when frozen the natural flavor is not affected, and the market value closely approximates that of fish freshly caught.

What care is necessary in freezing all products ?

Close attention should be paid to the economy of the process, as well as the excellence of the product.

What would this involve in the case of fish ?

The stock should be perfectly fresh and free from bruises and blood marks. It would improve the appearance and increase the value if they were graded according to size, but this is rarely done.

Do fish frequently deteriorate to some slight extent ?

They do; it depending: 1, on their condition when going into the freezer; 2, the care exercised in freezing; and, 3, the length of time they remian in store. The humidity of the storage room should be carefully regulated by use of unslacked lime or chloride of calcuim.

How does the loss in quality come about ?

It is due to evaporation which begins as soon as the fish are put in store and increases as the ice coating gradually disappears from the surface of the fish.

Can this evaporation be prevented ?

Not wholly, for it takes place at a low temperature although more slowly than at high ones. The ordinary loss is about five per cent in weight in six months, but the loss in quality is greater. The evaporative loss may be lessened by wrapping the frozen fish in wax or parchment paper and packing in boxes at the time they are frozen.

What are the principal fish frozen along the great lakes of the United States?

Whitefish, lake trout, lake herring, blue pike, saugers or pike-perch, sturgeon, perch, wall-eyed pike, grass pike, black bass. All these are considered good eating.

What are put in storage along the Atlantic coast?

Bluefish, halibut, squeteague or weakfish, sturgeon, mackerel, cod, haddock, Spanish mackerel, striped bass, black bass, perch, carp and pompano, and some others also considered palatable.

What on the Pacific coast?

Salmon, sturgeon and halibut.

Can all kinds of fish be frozen?

Some are too delicate to freeze, like shad. Oysters and clams should not be frozen; if stored in good condition, from 35 to 40 degrees, they will keep six weeks. Scallops and frogs' legs are frozen hard in buckets and stored from 16 to 18 degrees. Sturgeon and other fish too large for the pans are hung on meat hooks, and when frozen are dipped in water and then piled in frozen masses.

How long are fish sometimes stored?

Ordinarily, nine or ten months, but they may be in store even two or three years; in that case they are hardly fit for first-class trade, unless unusual care has been taken; they are usually frozen in the spring and fall.

How should the fish be frozen?

All kinds of fish keep and look best if frozen just as they come out of the water; only very large fish, like sturgeon, should be dressed. But as it is more or less the custom to send to the freezer the surplus of the fresh fish trade, many have already been split and dressed.

What was the first successful fish freezing process?

It was by Enoch Piper of Camden, Me., who used ice and salt. He employed that process in New York for several years in the freezing and storage of salmon, and finally his method was generally adopted by fish dealers.

Who improved on Piper's process?

William Davis of Detroit, in 1868.

How long was it before their processes were improved upon?

The introduction of mechanical refrigeration began in 1892. At that time ice and salt freezers were to be found at all the fishing stations on the great lakes, several were on the New England coast, and eight or ten were in New York City. Their aggregate capacity approximated 8000 tons.

How are the fish treated when sent for cold storage?

They are first washed in fresh cold water to remove the slime, blood, etc. They are then taken by hand and placed in an orderly manner in pans so that the cover when placed on the pans will come in contact with the upper side of the fish.

What is desirable in arranging the fish in the pans?

If the size permits, the bellies should be placed upward, as it is desirable to freeze that part first.

Where ice and salt are used about what is the proportion?

From eight to sixteen pounds of salt to one hundred pounds of ice, the proportion depending on the insulation and outside temperature. A coarse mined salt is largely used because of its cheapness, but a finer quality is more effective.

How is the mixing of the ice and salt done?

By scattering salt over each shovelful of ice as it is shoveled from the grinder into the wheelbarrow.

What determines the proportion of salt and ice required ?

It depends more on the fineness of the materials and their proportions, than on the outside temperature, humidity, or any other of the factors entering into the matter. The finer the ice and salt, the quicker is the freezing; the larger the proportion of salt, also, the quicker the freezing.

What is the proportion of ice and salt to fish ?

Eighty-five pounds of salt and 1000 pounds of ice to 1000 of fish. More is required during warm weather, as is also the case when the air is very moist.

How are the pans piled ?

Alternate layers of ice and salt two or three inches deep and then a layer of pans, and so on. The pile, for convenient handling, should not exceed six feet. A double layer of ice and salt is placed on top of the pile which should at the last be covered with wood or canvas, to exclude the air.

How long does this process of freezing take ?

Fifteen to eighteen hours.

When and where was the first refrigeration machine used ?

In Sandusky, Ohio, in 1892.

How does this machinery process of freezing fish differ from the old one ?

Instead of the pans of fish being placed in the ice and salt mixture, they are put on the pipes whether the circulation be brine or direct expansion

What is the best method of freezing fish ?

They are placed in galvanized iron pans and put on the freezing coils. When frozen they are passed through a bath of water which glazes them with ice. They can be frozen in twelve hours.

How are the pipes usually arranged?

In the freezing room they are from one-half to two inches in diameter and are arranged in shelves or nests, in horizontal layers, four or five, perhaps ten, inches apart, ranging from the floor to the ceiling. The pipes in the storage room are usually larger but not so numerous. They are arranged at the ceiling and sometimes about the upper side walls also.

What is the storage temperature?

From 16 to 18 degrees; above 20 degrees the fish are likely to turn yellow about the livers; this is thought to be due to the bursting of the "gall."

Should the storage room be dry?

Yes, for any moisture tends to develop mould on the fish.

What should be done in case mould appears?

Spray them with a solution of formalin and water, one part to nine.

When is celery usually stored and what is the required temperature?

About the time the ground freezes in the fall, and the best temperature is 32 degrees to 34 degrees. Some sorts may be kept one, others two and three months. "Dressed goods," so called, will keep only for a few days.

How is refrigeration used in making carbonated beverages, such as mineral water?

Water is cooled to 39 degrees Fahr., at which point it is bottled. At this temperature the density of the water is at its greatest and its absorptive capacity very large. Instead of using a carbonating pressure of 90 pounds or more the process is carried on at a much lower pressure, with less loss of bottles from breakage and increased safety to the operator.

STORAGE HOUSE OPERATION.

In the control and oversight of the modern refrigeration plant, be it large or small, nothing can exceed, in favorable results, the personal care of a superior man; that is, automatic mechanisms are less important than the watchful attention of experienced persons.

While this idea of the value of personality is true of all the arts and crafts, and always has been, it is particularly true of such manifold details as are set forth in the pages of this work.

This is owing to the varying circumstances which distinguish the art of refrigeration and preservation, and over which watchful personal supervision is necessary.

How does the temperature of the refrigerant affect the condition of a storage room?

In a room with a temperature of 33 degrees and a humidity of 70 per cent, the dew point would be 25 degrees. Therefore, any pipe surface at 25 degrees or lower will attract moisture. If the pipe surfaces are heavily coated with moisture, as they usually are when cold weather comes on, the frost acts as an insulator and the brine must be colder to do the work. Even then the frost finally gets so thick that no more frost will form; but for a time the room may be kept at the normal temperature owing to the largely increased cooling surface caused by the ice coating.

What is the remedy for this trouble?

By keeping the pipes outside the storage room, or by preventing the frost from forming on them.

What should be done when frost, moisture or water gets on the floor of a cold storage room ?

It should be taken up by dry sawdust or air slaked lime, and not allowed to sink into the floor or insulation.

After removing the frost what should be done then ?

Quicklime is placed around the room but not in a damp spot, as the heat of slaking might cause trouble. Chloride of calcium may be placed around in trays; also when it is cold and dry outside, the air from outside may be allowed to blow through.

What occasions a dripping ceiling ?

It may be caused by the cold floor above or pipes placed too near the ceiling.

About what is the allowance for rise of temperature due to persons and lights ?

For a person, 400 B. T. U. per hour.

For an ordinary gas burner, 300 B. T. U. per hour.

For a Welsbach light, 40 B. T. U. per hour.

For an arc light, 3 B. T. U., and an incandescent light, 10 B. T. U. per hour.

What is an important fact ?

As the temperature rises the capacity of the air for holding moisture increases, that is, the air is saturated at zero by .56 of a grain in a cubic foot, but at 100 it will hold 19.77 grains.

How should the rooms of new buildings be whitewashed ?

A thin coat is recommended for the first one; when this is thoroughly dry a thicker one for the second.

Are the quality and condition of goods improved by cold storage ?

No, it does not insure against natural deterioration; goods to be stored should be in prime condition and selected with care.

Do cold storage rooms require attention when empty ?

They do as much so as at any time, but in a different way.

Why is this ?

When cold weather approaches and the circulation is reduced, or cut off entirely, the frost on the pipes will begin to evaporate if it does not melt, and will make the air damp.

What will this lead to ?

To a growth of mould and a musty condition of the room.

How may this be remedied ?

Systematic whitewashing and ventilation will kill the mould, although it is much better to prevent its formation in the first place.

How long does it take whitewash to dry ?

From five to eight days. If it dries too fast, as it may when a salamander is used, it will flake off; while if drying is too slow the water will soak into the wood, giving the whitewash a mottled appearance.

How can the drying be forced ?

By the use of a salamander.

How should one be used ?

It is best to get the fire going well in the salamander before it is taken into the room in order to avoid the gases which are given off on starting.

Is whitewashing important ?

It is quite so. If not properly done butter may be flavored, eggs damaged, and other goods that are sensitive will be more or less impaired.

When should whitewashing be done ?

Preferably when the air outside is as cold or colder than the storage room.

What happens if the whitewash is too thick and does not dry ?

The water penetrates the wood and may lead to fermentation which will taint the room with a peculiar bitter or strong odor.

Which is best for whitewashing, hand or machine work ?

Hand work is preferable, for it makes a more smooth and even job. A machine will be of advantage in ceiling or overhead work which cannot be readily reached by hand. A machine is likely to put it on rather too thick, so that it will flake off if one does not go over it with a brush while it is green and make it smooth and even.

What is the most serious difficulty with the machine work ?

The thickness of the coat, and the consequent surplus of water.

What is considered good whitewashing work ?

It should look well, be white or nearly so, hard, not liable to flake or dust off, and should have disinfecting and germ-killing properties.

What is a very important part in the preparation of whitewash ?

The slaking, which should be carefully attended to, for if the lime is burned or "drowned" in slaking it is not firm in texture when applied, or as disinfecting as it should be.

How often should whitewashing be done ?

If rooms are used for egg storage, they should be whitewashed every year when the rooms are empty. It is better to whitewash every year anyway as it greatly lessens the danger from must and mould, and in a degree, from fire.

What is another method ?

Place the lump lime on a cement floor and sprinkle water slowly over it as it slakes. If this is carefully done it will produce a finely powdered slaked lime which may be mixed with water to the proper consistency.

Is this as good a method as the first one ?

No, because it is slower, and there is more danger of "burning" the lime and making the whitewash lumpy.

What process of making whitewash do others employ ?

Whitewash made by a government formula.

What is the objection to this ?

Because it contains rice boiled to a thin paste, and it is advisable to avoid organic substances using only mineral ones.

Is it advisable to add any salt ?

When the lime is thoroughly slaked in the half barrel, add a peck of salt and more water to maintain the proper consistency, or dissolve the salt in boiling water and add the solution.

How is whitewash used ?

In a thin paste; it may be tempered as used. To each twelve-quart pail of whitewash as it is ready for use, add a good handful of Portland cement and a teaspoonful of ultramarine blue. The cement will make it adhere better to the surface and the blue will counteract the brownish color of the cement. If white hydraulic cement is to be had, use that, as it is better than Portland. It will not then be necessary to use the blue, but half a teaspoonful to a pail will make a whiter surface. The wash should be strained through a fine wire cloth in order to remove lumps.

What is the objection to whitewashing in the summer ?

Because it is then difficult to get it dry.

What is used besides whitewash ?

There are a number of good cold water paints. For butchers' boxes or retail coolers they are, perhaps, better than whitewash, for they will not peel or flake off. Some of them contain glue or other organic substances which it is unadvisable to use in cold storage rooms. Shellac looks well and is water proof, but it has no cleansing or disinfecting properties like whitewash.

Why are oil paints to be avoided ?

An oil paint, or other preparation which has any odor, should not be used in a cold storage warehouse.

How should lime be slaked ?

Take an oil or vinegar barrel and cut it in two or down to half size; put in a half bushel of lime and pour over it enough boiling water to cover. A piece of one inch gas pipe should be used to keep it well stirred down to the bottom. If it slakes very quickly two persons will be needed, one to pour water and the other to stir. The two should keep at work until the lime is all slaked and reduced to a thin pasty solution.

Why should this care be taken ?

Unless the stirring is done, the slaked lime will contain small pieces or lumps which are not slaked but "burned" because the water did not come in contact with them at the right time.

Is boiling water necessary ?

No, but it facilitates the work and does it more thoroughly.

On what does the humidity of a cold storage room depend ?

It depends on the season and the ventilation.

How does air take up water ?

The water exists as a vapor diffused through the air after the manner of a mechanical mixture.

Can cold storage rooms be thoroughly deodorized ?

If rooms have been used for a long time for some strong smelling product, without being properly aired out, the problem is a difficult one. Example: To change from vegetables and fruits to butter and eggs demands a sweet and well ventilated room.

How may storage rooms be disinfected ?

By formaldehyde vapors burned in lamps made specially for this purpose. The wick is covered by a thimble-shaped platinum wire screen, which is made to glow only and not burn with a flame.

Are some cold storage products more liable to damage in cold than in warm weather ?

Yes, those which are carried about 30 degrees Fahr.

What is the explanation of this ?

If ice bunkers are used, the ice ceases to melt when cold weather comes on, so that circulation ceases and the impurities which have collected on the surface of the ice begin to evaporate. If the cooling be done by pipes, the same effect is produced, for the circulation of brine or ammonia, as the case may be, nearly ceases when cold weather comes on, and the frost on the pipes begins to melt and also throw off impurities. In either case, the air before long becomes laden with impure vapors and they soon affect the goods.

What should be done when a cold storage house cuts down or shuts off its pipe circulation ?

The pipes should be cleaned externally or the frost will soon begin to thaw and throw off foul gases and other impurities.

What should be done ?

A large amount of calcium chloride should be exposed to the air.

How may this be done ?

By placing it on a shallow pan or trough near the ceiling, as the greatest humidity is there. The tray should slant a little and be provided with a pail to catch the drip. A better way would be to have a wire tray to hold the calcium just over the drip tray as it will insure a better air supply for the calcium. (See page 544).

What is another plan to be used when shutting down ?

A tight box containing several wire screens of calcium chloride, one over the other, and having a drip tray under them all. The moist air is taken from the top of the room, forced in at the bottom, passed through these trays, and comes out as dry air at the top, and is then discharged at the opposite end of the room.

How does this compare with the other processes ?

As in this case a fan is used, it is more rapid than the others.

How much is the efficiency of the pipes increased by ridding them of frost ?

From fifteen to twenty-five per cent.

Is the expense of doing this large ?

No, the apparatus is not expensive and the cost of calcium comparatively low.

What is the action of this brine on the pipes ?

The pipes will not rust if kept continually wet with it.

How much frost will form on the pipes of a 20,000 cubic foot storage room in a season ?

Something like 2,000 pounds.

What is claimed for this process in point of economy ?

That by keeping the coils clean the necessary piping is much reduced in quantity.

How should the moisture be regulated ?

The room must not be either too dry or too moist, for in the former case the goods will dry and shrink, while in the latter they are liable to become mouldy. There is much less liability of the former though than the latter.

Can the use of chemical dryers be reduced to a minimum ?

Yes, if the frost is kept off the pipes.

Where are absorbents most used ?

In storage houses cooled by use of ice; they are especially used to take up the moisture from fruit. Reference is made to the use of unslaked lime and lumps of chloride of calcium.

In what forms is lime used in cold storage rooms ?

Unslaked, air slaked, and in the form of whitewash.

Why is lime for this use less valuable than calcium ?

It has not as large capacity for taking up moisture. Lime simply air slakes; that is, it absorbs just moisture enough to disintegrate in form of a powder.

How is air slaked lime useful ?

While air slaked lime will absorb very little moisture, as it gives off minute particles of lime it has some effect in preventing fungous growth.

What is the most satisfactory way of using lime ?

Place lumps of quicklime around the upper part of the rooms in trays or pans.

How much greater value as an absorbent has calcium than sodium ?

While the latter will absorb sufficient moisture to become damp, the former will take up enough to lose its solid form.

Is there any relation between moisture and the impurities present in a cold storage room ?

Yes, for water has a great absorbing power for gases and other matter.

How does the quantity of goods in a room affect the humidity ?

The pipes are constantly absorbing moisture and if there is only a limited amount of goods in the room to give it off the humidity will be likely to go lower than if the room be full, unless the humidity is regulated, thus indicating the value of an air circulation. Unless there is a proper circulation, a room partly filled with eggs will turn them out shrunken and evaporated, and if the room is full they may be musty or mouldy.

Will the absorption of moisture have a tendency to purify the air ?

It will to a large extent, consequently the more thoroughly the air is circulated and brought in contact with the means for absorbing the moisture the better.

Will the removal of moisture absolutely purify the room ?

No, for water in the form of moisture has little absorbing power for certain gases.

How can we prove that fresh air from outside is occasionally necessary in order to maintain perfect conditions where goods are stored for long periods ?

Because cold storage rooms are seldom free from odors.

What is the worst impurity found in cold storage rooms ?

Germs which produce fungous or mould.

Where do they come from ?

They are probably everywhere present in the atmosphere and only need favorable conditions of moisture and temperature to develop.

How can we show that this is so ?

In the dry mountain air of Colorado and California freshly-killed meat may be hung in the open air without decomposition, but it would soon be unfit for food if it was exposed in the moist tropical climate of Cuba or Florida.

What in cold storage are also important besides the temperature ?

The air circulation, ventilation and humidity must be looked after.

What is the difference between ventilation and air circulation ?

Ventilation means the introduction of fresh air from outside for the purpose of purifying a room. Circulation refers only to the movement of air in the room.

Why is air circulation necessary ?

The air must be purified, as nearly all goods give off moisture and along with it finely divided decomposed matter. Gases resulting from this surface decomposition, and the ripening of the goods in some cases, are also present; other moisture is continually finding its way in by the opening of doors, leakage through insulation, and from the breath of persons in the rooms.

Why is ventilation necessary ?

Because there are some gases and impurities which water does not absorb.

How in practice is ventilation differently regarded ?

Some houses are not ventilated except when they are opened in the spring and fall for whitewashing; other houses are given none at all except when the doors are opened for receiving or delivering goods.

How should ventilation be regarded ?

As absolutely essential both for heating or cooling rooms.

How does ventilation come about to some extent naturally ?

By leakage of air through windows, doors, etc.

How does air leakage take place ?

If the outside air is very much warmer, the cold air in a storage room will collect in the lower part of the room and tend to flow out there and the warm air will come in at the top, both currents going through any crevices they can find. If the outside air is colder than the room, the direction of the current is reversed.

What should be the condition of the air before it is brought into a cold storage room ?

It should be fresh, without excessive moisture, and as free as possible from impurities and germs.

How does city air become contaminated ?

By exhalations from the breath of men and animals, the evaporation from the soil, dust and decaying matter of various kinds in the streets, and also the products of combustion from furnace fires.

What is the most objectionable impurity from a cold storage point of view ?

Germs, which under the influence of moisture and warmth make mildew or mould.

How does a rising temperature increase this danger ?

The warmer the air, the greater its capacity for holding moisture, and the more rapidly the germs propagate.

What may be the result of natural systems of ventilation ?

If the temperature outside and inside the room is nearly the same, there will be little change of air, even if windows or doors are opened; if the outside air is cold enough its coming in would freeze the goods.

Is ordinary ventilation suitable for cold storage rooms ?

No, for the reason that the problem is how to get fresh air without a strong draft.

How may the cold storage ventilation problem be stated ?

In warm weather the air for ventilation of refrigerator rooms should be of about the same temperature and humidity as the air in the room itself and be free from germs, and as it is not easy to secure these conditions it is best to do the ventilating artificially in the house.

What large error have some cold storage managers sometimes made ?

By simply cooling the air to the temperature of the storage room; for, while the percentage of moisture is not reduced, the capacity of the air for holding it is greatly lessened, so that the air is saturated, and the moisture is not only liable to be deposited on the goods, but is in condition to rapidly develop mould.

What is one way of remedying this unfavorable condition ?

By cooling the air, before it enters, five or six degrees below the temperature of the storage room.

What is the objection to this ?

That nothing has been done for the purification of the air.

What is quite necessary in introducing fresh air ?

To provide an outlet for the impure air.

Where should this outlet be ?

Near the floor and of area equal to the inlet flue.

Is it practicable to wash the air ?

It is difficult to force air through water or brine with a fan.

Describe Madison Cooper's system of warm weather ventilation ?

First, the use of an air washing tank in which the air flows upward against a rain or water from a perforated diaphragm above. This reduces the air to the temperature of the water, say 55 to 60 degrees, and also takes out a large share of the impurities. Second, the air goes into a cooling tank in which it is reduced to a temperature several degrees below that of the storage room. This removes the moisture which holds in suspension the few impurities that may have passed the washing tank. Third, comes the drying box which contains chloride of calcium in lumps placed, as shown on page 544; what moisture may be left is taken out here, making the air clean, cool and dry.

What is said as to volume of air necessary for ventilation ?

Some think the whole volume of air should be changed once a day, others prefer twice; probably once or twice a week is often enough.

To what time of year have the foregoing remarks been applicable ?

To the time when the outside air has been warmer than the air in the refrigerator.

How may ventilation be accomplished in cold weather ?

It is quite safe to force in plenty of air when the temperature of the outside air is about the same as the storage room but one should first consult a sling psychrometer (see description on page 558). The only chance taken would be the question of impurities and the risk would not be great in a cool crisp day.

Could this be done when the outside air is considerably cooler ?

It is safe, so far as humidity and impurities are concerned, if it be warmed to agree with the temperature of the storage room.

Could the forced circulation fan be used for ventilation ?

It is better to have two, the second fan for ventilation only.

What is the whole theory of ventilation ?

If air is wanted at a particular place, at a particular time, it must be put there somehow. Some methods may give at times satisfactory results under certain conditions, but a fan can be depended on under all circumstances.

What are two general methods of handling air for ventilation ?

The plenum or pressure method and the vacuum or exhaust method.

Why is the former preferable ?

If the air be exhausted, the vacuum will drag in air from every pore and crevice, bringing in moisture and germs.

How is the pressure method used ?

The air is forced into the cold storage room by a fan after being cooled, dried and purified, is the best practice.

How may fairly satisfactory ventilation be accomplished without power fans ?

By air ducts from the various rooms leading to a common terminal which goes upward beside the chimney, the warmth of the chimney gases establishing and maintaining the circulation.

How are the foul gases removed ?

As they tend by gravity to fall near the floor, an outlet for them should be provided in the lower part of the room. The pressure of the incoming air will force them out, so that if there is any air leakage it will be where it is wanted, outward.

Is air ever perfectly saturated or totally without moisture ?

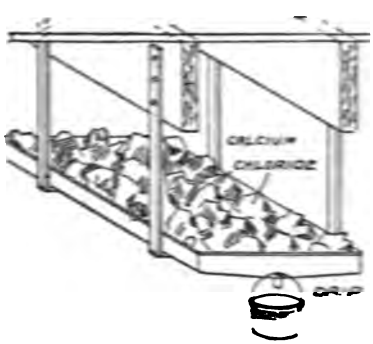
ver reaches either extreme.

How about ventilation of egg storage rooms ?

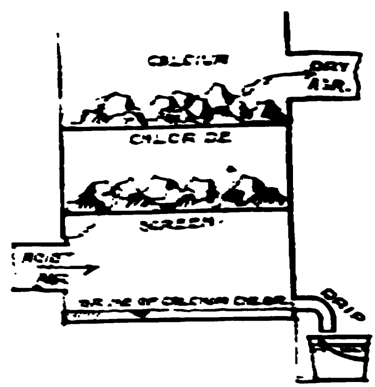
Cooper recommends that some chloride of calcium be placed over the coils, whether the latter be brine or direct expansion. As the calcium absorbs moisture it forms a brine which will trickle down the coils, thereby preventing formation of frost, thus purifying the air and also taking out undue moisture.

What are the desirable features of this plan ?

It gives fresh air which is necessary for some classes of perishable goods, such as eggs, cheese, fruits, meats, etc.



SUSPENDED TRAYS OF CALCIUM CHLORIDE.



CALCIUM CHLORIDE TANK.

Should refrigerating pipes be painted ?

No, it is not necessary and it may do harm.

Is it advisable to paint galvanized pipes, tanks, or iron or steel surfaces used about refrigerating rooms ?

No, as it may be a positive detriment in the circulation of an odor. Galvanizing takes the place of paint.

What is the main objection to painting when they are in place ?

No paint is without odor.

Why is a circulation of air necessary ?

Because in order to remove the moisture from the air in a cold storage room it must be continually moving in contact with pipe surfaces or other means of absorbing moisture.

How does this affect the goods ?

The upper tier of goods will be cooled by the ceiling pipes, and each tier down will be cooled by radiation and conduction into the one above.

What is the best arrangement of piping ?

On the walls rather than from the ceiling.

How is the cooled air circulated ?

Either by natural circulation, which is not wholly satisfactory, or by some means of forced circulation, such as ventilators or fans.

What is the main objection urged against a forced air circulation ?

That it will lead to drying out of goods and packages.

What is this supposed evaporation dependent upon ?

It depends on the dryness of the atmosphere, so that it hinges on regulating the humidity.

Can humidity be controlled ?

It is as easy as it is to control the temperature, and if both are regulated, and the circulation of air is well distributed, there will be no danger from evaporation.

What class of goods is particularly liable to evaporation ?

Cheese.

What factors control the natural gravity air circulation ?

Outside weather conditions, temperature of room, temperature of refrigerant in pipes, length of time goods have been in storage, etc.

How does the circulation take place when direct expansion or brine piping is used ?

The cold air falls down through the coils and the warm air rises among the goods; this is natural gravity circulation.

What is a very good system where goods do not give off much moisture ?

Where the cool air comes in through ducts on opposite sides of the room and the warm air passes out through a duct in the middle of the ceiling.

How may goods be packed where this system is used ?

With thin strips on the floor a fraction of an inch between goods, and at the sides of the room.

How much ceiling space is needed ?

Half an inch.

Why is a forced circulation better than a gravity circulation ?

It promotes economy of space in storing goods and produces better results.

How is the air cooled in the air circulation system ?

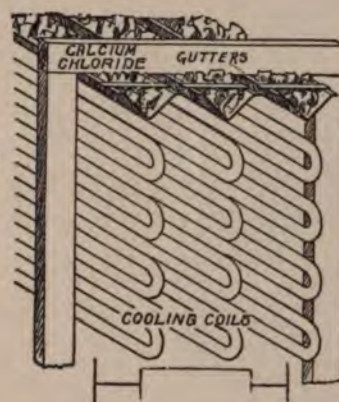
By passing the air over ammonia or brine coils.

How is this plan operated ?

By grouping pipes in a room where air is cooled by being passed over the pipes; the air is afterwards forced by blowers into and through the rooms to be cooled.

What is one very efficient plan of circulation ?

An authority of high standing proposes for a storage room a perforated false bottom and a perforated false ceiling, the space between the former and the floor being connected with the cold air duct, and the warm air duct leading from between the false and real ceiling. (Cooper).



How much room do the false floor and ceiling take up ?

One and three-fourth inches for the floor and one and one-fourth for the ceiling.

How does the system work in practice ?

After the room is filled with goods and cooled to the proper temperature, no difference in temperature can be observed in different parts of the room, and only a gentle flow of air is noticeable.

What are the advantages of a forced air circulation system ?

A more equal distribution of air, saving in space, and when the air is perfectly distributed it is not necessary to circulate a large volume.

What are the objections to it?

The expense and the probability of dirt collecting beneath the floor. As to the latter objection, the floor may be made in sections and easily taken up.

How much more storage room may be utilized by this system?

From five to ten per cent.

How much pipe is needed?

About half to two-thirds as much as for a direct piped room.

How much power is required to operate the fan?

About half a horse-power for 15,000 cubic feet of space.

What are two important advantages of a forced circulation?

In winter, when the circulation is cut off from the pipes, their frosted surfaces are not exposed in the storage rooms and it is easy to clean the pipes.

What process does Mr. Madison Cooper use in this connection as shown in the cuts on page 547 and page 549.

He so arranges chloride of calcium over the pipes that as it absorbs moisture it trickles down over the pipes and keeps them clean.

What trucks are used for handling goods?

First, small hand trucks on two wheels; second, four-wheel ones, 30 inches wide and 5½ feet long. In large plants those a little longer and wider may be used, if doors and corridors have been planned for them.

What are the two types of four-wheel trucks?

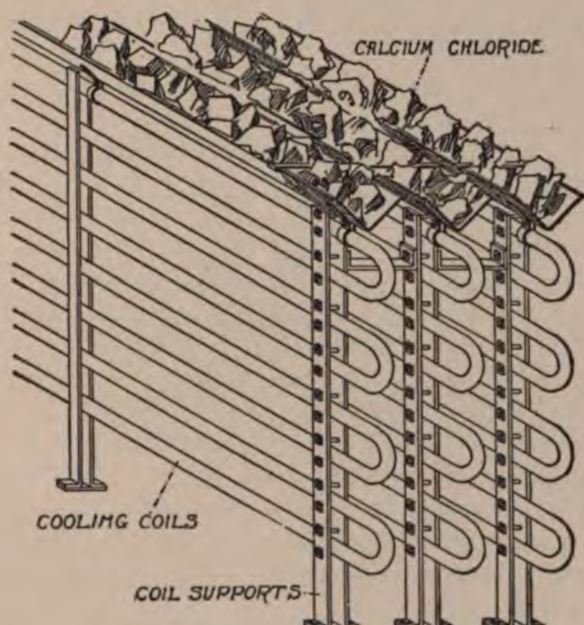
One has two large wheels in the center and a small wheel or caster at either end; the other type has two large wheels a little distance from one end and two casters at the other end. This second type is better for inclines and is generally used. Trucks should have a hand rail at one end only.

Is ice used at all in cold storage warehouses ?

Yes, there are seven warehouses in one group, aggregating 400,000 cubic feet, using ice and salt, and keeping freezing rooms from 10 to 15 degrees, and eggs at 30 degrees in a pure and dry atmosphere.

What are the lowest temperatures practicable from melting ice ?

36 to 38 degrees during warm weather.



How is this temperature still further lowered ?

By mixing salt with finely crushed ice. This will give a temperature a little below zero.

Is it practicable to obtain this zero temperature ?

No, not for a room, only locally around the ice and salt.

Can air be circulated satisfactorily directly from the ice ?

There is always trouble from dampness, which soon produces mould, also decay of woodwork and the insulation.

What are the two main disadvantages in an ice cooled warehouse ?

Contamination of one room by another, and no control of humidity is possible.

Can it be used for long period storage ?

Not for eggs, butter, cheese and fruits.

For how long a term only is ice storage satisfactory ?

From one to three months. An attempt to build up a permanent miscellaneous business, especially for butter and eggs, cannot be accomplished by ice storage alone.

Describe Cooper's Gravity Brine System ?

He has a tank in the upper part of the building containing a coil, which is connected with cooling coils in the storage room. These coils connected together are, in fact, one continuous coil, the part in the tank on the upper floor being surrounded by crushed ice and salt. The circulation system contains chloride of calcium brine, which is cooled as it passes through the tank coil and, being heavy, falls into the cooling room coils, and the brine in the cooling coils being warmer and lighter is forced up into the tank coil, where it is cooled again. He thus obtains an automatic circulation, it being necessary only to fill the tank with ice and salt once a day.

The more thoroughly the ice and salt are mixed together the better the freezing action.

What results may be had from its use ?

Cooper claims a temperature of 6 degrees Fahr. by his gravity brine system, and says temperatures of 12 to 15 degrees are easy to maintain.

Is chloride of calcium used ?

Not largely, as it costs double the price of salt.

What is the condition of the storage room with this system ?

Practically the same as from any other system of brine circulation.

What labor and power does this system require ?

The ice is usually crushed and elevated by machinery. Two men can handle four tons of ice per hour, and this amount will take care of a house of forty car load capacity for one day of average summer weather.

On what do the effective results depend ?

On the amount of salt used, say from 5 to 15 pails, 25 pounds each, for a tank 4 x 5 x 10.

What depth does Cooper recommend for tanks ?

About ten feet.

How should the ice and salt be mixed ?

Incorporated as thoroughly as possible.

What does he say about charging the primary tank ?

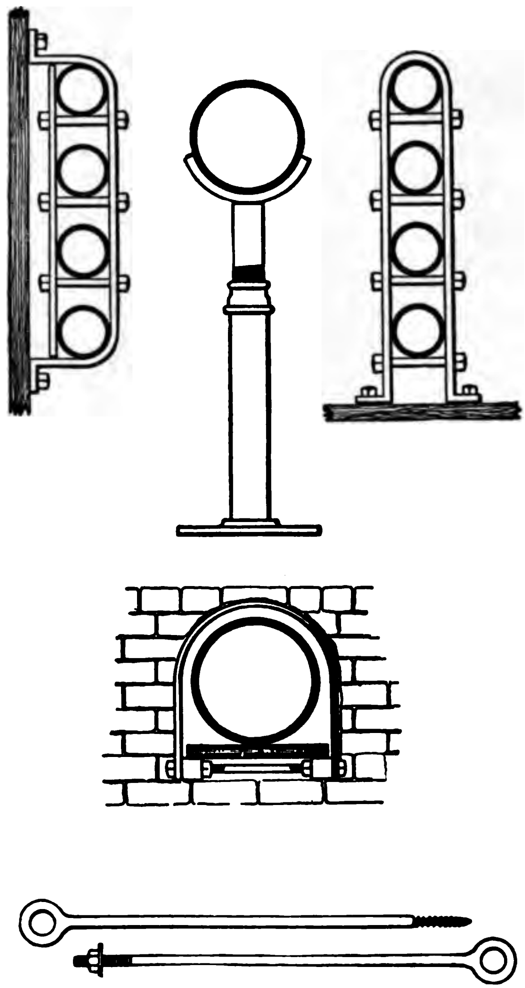
The ice and salt can be mixed before putting in the tank, but as the ice is fed in from the spout. it is more convenient to put the salt in then. The finer the ice the better. It is the best plan to have one man put in the salt and the other to stir it in.

Are there any limitations to Cooper's gravity process ?

It works well, down to 12 degrees Fahr., but the melting of the salt is very slow or practically inoperative below that.

What is the system capable of doing, say at 30 degrees ?

At this temperature the action is rapid and no trouble is experienced in keeping a sixteen pipe coil free from frost.



Methods of supporting pipes.

MEASUREMENTS.

All civilized nations have at an early day used units of measurement, such as foot, yard, inch, fathom, pound, etc.; hence in every trade and occupation of life some combination of instruments and calculations is indispensable.

What is the thermometer?

In its usual form a body of mercury inclosed in a glass tube; the increase or decrease of temperature causes the mercury to expand or contract, and its variations are indicated on an attached scale.

Are other substances beside mercury used?

Alcohol, or even air may be used.

What are the three different scales?

The Fahrenheit is used in the United States; the Réaumur in Germany; and the Celsius or Centigrade in France, and, for scientific or technical purposes, more or less all over the world.

How do they differ?

In the former zero is 32° below freezing, and the boiling point 212°. In the Réaumur zero is put at the freezing point, and the boiling point is made 80°. In the Celsius the freezing point is zero and the boiling point 100.

How low a temperature may be obtained bv the use of crushed ice and chloride of calcium?

Many degrees below zero.

How are high temperatures measured?

By pyrometers of various types.

What thermometers should be used ?

Only those that have the graduations etched on the stem. Special cold storage ones, marked from zero to 50°, may be had. When bought new they should be hung side by side with an old one that is accurate. It is a good plan to have a place to hang them when not in use, side by side, so that they may be compared. Cheap ones are frequently from two to four degrees out of the way.

Where should mercury wells and thermometers be placed ?

In the suction pipe where it enters the compressor.

On the discharge pipe where the gas leaves the compressor.

On the discharge pipe where the gas leaves the condenser.

In the supply and discharge manifolds of the refrigerator.

In the brine pipe where it discharges into, and returns from the refrigerator.

How often should readings be taken ?

Where the duty required of the machine is pretty even, readings need not be taken oftener than once every half hour, but if it varies considerably, once every quarter hour is not too often. Diagrams of steam cylinder and compressor should be taken every three hours.

How should thermometers be placed near the compressor ?

Accurately graduated thermometers inserted in the suction and discharge pipes of compressors indicate many of the things which the ammonia compressor records. The value of thermometers on the suction and discharge pipes of compressors is not wholly appreciated even by the technical refrigerating engineer, and much less by the practical operating engineer, who too often considers that in putting his machinery in good working order once a year he is relieved of his responsibility so far as economical operation is concerned.

In what other places should they be put?

If the engineer has had thermometers installed at the various places, viz., one on the liquid ammonia pipe near the expansion valve, one between the expansion valve and the freezing tank, one on the absorber, one on the weak liquor pipe near the absorber, and one on the boiler feed pipe between the pump and the steam boiler and kept a record during the busy season as to the various temperatures, including cooling water and brine, he will have no trouble in locating the deficient part of the machine or any of its adjuncts.

What instruments are used in measuring higher pressures?

Aneroid gauges.

What are manometers?

Mercury gauges used for measuring higher pressures than those of the atmosphere.

What are hydrometers?

They are instruments based on the Archimedean principle, intended to show the specific gravity of liquids and inferentially their strength.

How are they made?

The common form has a weighted body at the bottom, usually of glass, to make it stand upright, the upper part having a delicate graduated stem. The degrees may be arbitrary and refer to a separate table, or they may indicate directly specific gravities, or strength of some particular liquid or solution in percentages.

Should the strength of the brine be carefully watched?

It should be tested every day.

How is brine tested?

By a special hydrometer called salometer or salinometer.

How is it graduated?

By divisions indicating the density of sea water, that is, sea water contains $\frac{1}{33}$ of its weight in salt, so that one division on the salometer would indicate the same proportion in the brine, two divisions twice as much, and so on.

How is the instrument in general use divided?

The one commonly used for brine indicates 25% solution, by weight, of salt at the 100 reading, with the lower figures proportionally.

How do salometers differ for temperature?

They are made and graduated for the purpose they are intended for, the marine boiler type being used at a temperature of 200° or very near the boiling point.

How is the salometer used?

It is scaled from zero of pure water to 100, which is about the point of a saturated solution of salt brine.

What should be taken into consideration in using tables?

As the percentage of calcium given in the table represents the total per cent., it must be borne in mind that the commercial fused chloride of calcium contains about 25% of water, so that about 33% more will be necessary than is stated in the table.

How is the humidity determined?

By hygrometers and psychrometers.

Describe the former.

It depends on the contraction and expansion of some substance, as a human hair, which is affected by the moisture in the air. The hair is fastened at one end, the other passing around a pulley to which is fastened a pointer that moves over a graduated scale.

What is the advantage of the hygrometer ?

The scale is graduated from zero to 100 so that the percentage is read at a glance, but these instruments are affected by changes of temperature, and the reading may be varied by shocks or vibration. Further, they are expensive, and must be hung in a room for some time in order to obtain an accurate reading.

What is a psychrometer ?

It is simply two thermometers mounted on one frame, the bulb of one being covered with muslin and connected by a cord with a small reservoir of water beneath. Capillary attraction keeps the muslin around the bulb always wet. The evaporation of water from the wet bulb, which depends on the humidity of the atmosphere, cools it somewhat, and the difference of the thermometer readings referred to a prepared table gives the relative humidity.

How many kinds of these instruments are there ?

Two; stationary and sling.

What is the difference between them ?

In the former the muslin dips into a reservoir of water and the instrument hangs on the wall like the hygrometer, and it also requires some time to take a reading.

The sling pattern has a handle for whirling; there is no reservoir of water, but the muslin surrounding the wet bulb is dipped in water when an observation is to be made. When it is rapidly whirled some of the water will be absorbed by the atmosphere, and the comparison can be made as before.

Do these instruments require repairs ?

The muslin and cord should be renewed from time to time.

How must care be taken ?

That the wet bulb does not become dry.

How is the sling pattern used ?

Dip the muslin covered bulb in a small cup of water, then whirl for 10 or 15 seconds and dip again and whirl for 10 or 15 seconds more, then read quickly, the wet bulb first; repeat the whirlings once or twice, noting the reading each time; when two successive readings of the wet bulb very nearly agree the lowest point has been reached. If the water used be of about the same temperature as the room correct readings are sooner obtained. If the water and instrument are of a much higher temperature than the room it will take longer but the result will be as accurate.

The handle is held horizontal, the body is not moved very rapidly. In a storage room hold it as far from the body as convenient and in the direction from which the circulation comes. Take the reading as quickly as possible and do not allow the breath to strike the instrument.

How low temperatures will these instruments indicate ?

A stationary psychrometer is useless below 32° as the water will freeze, and on the sling 29° dry and 27° wet are about as low as one can depend upon.

How does Prof. Marvin advise the use of his sling psychrometer ?

The instrument consists of a pair of thermometers, provided with a handle, which permits the thermometers to be whirled rapidly, the bulbs being thereby strongly affected by the temperature of and moisture in the air. The bulb of the lower of the two thermometers is covered with thin muslin, which must be wet at the time an observation is made and kept in good condition. The evaporation of the water from the muslin always leaves in its meshes a small quantity of solid material, which sooner or later somewhat stiffens the muslin so that it does not readily take up the water. This will be the case if the muslin does not readily become wet after being

dipped in water. On this account it is desirable to use as pure water as possible, and also to renew the muslin from time to time. New muslin should always be washed to remove sizing, etc., before being used. A small rectangular piece, wide enough to go about one and one-third times around the bulb, and long enough to cover the bulb and that part of the stem below the metal back, is cut out, thoroughly wetted in clean water, and neatly fitted around the thermometer. It is tied first around the bulb at the top, using a strong thread.

A loop of thread to form a knot is next placed around the bottom of the bulb, just where it begins to round off. As this knot is drawn tighter and tighter the thread slips off the rounded end of the bulb and neatly stretches the muslin covering with it, at the same time securing the latter at the bottom.

To make an observation, the so called wet bulb is thoroughly saturated with water by dipping it into a small cup or wide mouthed bottle. The thermometers are then whirled rapidly for fifteen or twenty seconds; stopped, and quickly read, the wet bulb first. This reading is kept in mind, the psychrometer whirled again, and a second reading taken.

This is repeated three or four times, or more, if necessary, until at least two successive readings of the wet bulb are found to agree very closely, thereby showing that it has reached its lowest temperature. A minute or more is generally required to secure the correct temperature.

When the air temperature is near the freezing point it very often happens that the temperature of the wet bulb will fall several degrees below freezing point, but the water will still remain in the liquid state. No error results from this, provided the minimum temperature is reached. If, however, as frequently happens, the water suddenly freezes, a large amount of heat is liberated, and the temperature of the wet bulb im-

mediately becomes 32°. In such cases it is necessary to continue the whirling until the ice covered bulb has reached a minimum temperature.

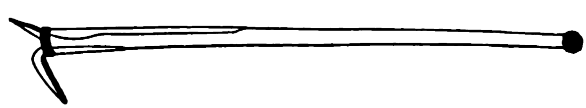
It is hard to describe these movements; the arm is held with the forearm about horizontal, and the hand well in front. A peculiar swing starts the thermometers whirling, and afterward the motion is kept up by only a slight but very regular action of the wrist, in harmony with the whirling thermometers. The rate should be a natural one, so as to be easily and regularly maintained. If too fast or irregular the thermometers may be jerked about in a violent and dangerous manner.

The stopping of the psychrometer, even at the very highest rates, can be perfectly accomplished in a single revolution, when one has learned the knack. This is only acquired by practice, and consists of a quick swing of the forearm, by which the hand also describes a circular path, and, as it were, follows after the thermometers in a peculiar manner that wholly overcomes their circular motion without the slightest shock or jerk.

The thermometers may, without very great danger, be allowed simply to stop themselves. The final motion in such a case will generally be quite jerky, but, unless the instrument is allowed to fall on the arm, or strikes some object, no injury should result.

What is a mercury well?

It is simply a short piece of pipe, closed at one end and fitted tightly into a pipe or vessel whose temperature is to be ascertained. The pipe is filled with mercury and a thermometer is placed in it. (See pages 101 to 104).



Ice Hook.

COLD STORAGE HOUSES.

Warehouses for cold storage are mostly located beside railroads and other means of transportation.

Among the latter may be named canals, wharfs, turnpikes, and the streets of large agricultural towns.

The size of these structures must, from necessity, greatly vary, and be determined by local surroundings and the extent of trade which they serve.

The location of a successful cold storage plant is also decided by its convenience to the regular flow of trade.

What should be the shape of a cold storage building ?

As nearly a cube as possible, provided there are no conditions requiring it to be otherwise; that is, the length, breadth and height should be nearly equal.

How do medium size storage houses compare in cost ?

A frame building of 20 car-load capacity costs from $8,000 to $10,000; one of 80 car-load capacity from $20,000 to $30,000.

Why is it necessary to operate refrigerating machinery continuously ?

Even after the internal temperature of the house has been reduced, from ½ to ⅞ of the power in use is needed to take up the heat that passes through the walls.

Why is good insulation of the highest importance ?

Because lack of efficiency not only makes necessary a larger machine, but the cost of after operation is greater.

What is the estimated loss of refrigeration in an imperfectly insulated warehouse ?

It is estimated that at least four-fifths of the work is expended in taking up heat which comes through the walls.

What other trouble comes from poor insulation ?

The difficulty in keeping a uniform temperature in the various rooms of the house.

What are the advantages of a first-class insulation ?

1. Less piping is required.

2. In case of accident to machinery temperatures may be held longer until repairs can be made.

3. Valuable stores will often be saved from injury.

What are the requirements of an insulating material ?

1. It should be odorless, so as not to taint perishable goods.

2. It should not attract moisture, and if it should become damp it must not rot or ferment.

3. It should be rat-proof and give no inducement for vermin to nest in it.

4. It should not be liable to inherent disintegration or spontaneous combustion.

5. It should be of light weight, but solely because light materials are better non-conductors than heavy ones.

6. If used as a filler, it should be elastic enough to keep its position firmly.

7. It should be reasonably cheap.

8. It should be suitable for practical application in general work.

9. It should be water-proof and fire-proof, or, at least, fire-retarding.

Do all non-conductors possess these last two qualities ?

No, not in themselves.

Are both essential ?

The former is the more important because materials that are wet or damp, transmit heat more readily than dry ones, so that the water-proofing is usually obtained by putting water-proof material around the non-conductor. Fire-proofing is frequently desirable, and it is accomplished by putting masonry walls, Portland cement, plaster, or other non-combustible material, also around the non-conductor.

In a properly constructed building how does the cost of insulation figure ?

It will be from 50 to 65 per cent of the cost of the building.

Cold storage partition.

What general idea may be had as to the cost of insulation ?

For temperatures from 30° down to zero F. it will cost from 25 to 50 cents per square foot for insulation in place.

What is the modern theory of insulation ?

That a composite one is the best.

What is composite insulation ?

Any construction in layers made up of materials having different densities and varying values as insulators.

What is the theory in regard to composite insulation ?

If heat in passing from one exposed surface to another is obliged to pass through strata of different densities a loss of heat takes place at each change of density.

If a cold storage warehouse is made of the so-called "mill construction" what materials can be used for insulating ?

Cork, lith, hair felt, linofelt, silicated paper, air spaces, etc.

If a building must be made fire-proof, to what materials is its construction restricted ?

Mineral wool, mica and calcined pumice, and cork and lith board.

How may insulation be tested ?

A box may be made of the material to be tested and put in a room of even temperature. A certain quantity of ice is then placed in it, and the water running off through a drain pipe. due to its melting, is weighed, and the value of the insulation thus determined.

In fire-proofing how is the interior finish of importance ?

Hard oils, varnish, shellacs, etc., are very inflammable, while cold water paint or whitewash is not.

Why is air efficient for insulating ?

Because it is one of the best of non-conductors.

What is the objection to air, as it is so good a non-conductor ?

It must be motionless, a very hard condition to bring about.

How is this difficulty overcome to a large extent ?

By confining the air in small areas so as to prevent circulation, and con[illegible] small spaces and filling with some material.

How should this material be packed ?

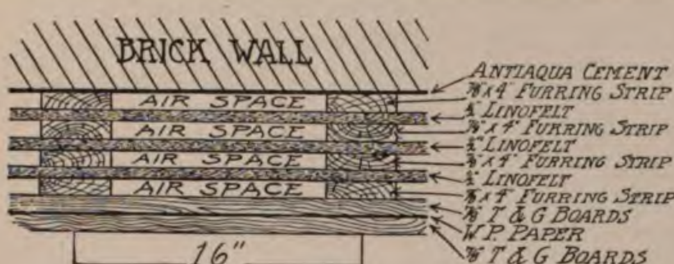
Not too loose or too hard. Cooper says about nine to twelve pounds per cubic foot. Starr thinks ten pounds right.

Does tight packing increase the insulating value of certain substances ?

Some materials, which in a natural state are of little insulating value like straw, sawdust, wood or cork shavings, may be packed very tight, and their insulating properties will be increased.

How has insulating material been greatly improved ?

It has been made in sections that are easy to handle and put in place.



Insulation on brick wall.

What are now mainly used for insulating materials ?

Cork board and mineral wool board.

What should be taken into consideration in applying any sections of insulating material ?

They should not be expected to hold nails or support the structure, nor should the fact be overlooked that they are not absolutely air or moisture proof, as delivered from the factory.

[redacted]

Why is packing used ?

To break the air spacing into small cells, for air spacing properly designed affords the very best insulation.

What is necessary to consider in cold storage calculations, both for ice making and refrigeration ?

The refrigeration necessary to provide for the radiation through the walls, and that needed to cool the goods that may come in down to the temperature of the room. A very close calculation would also make it necessary to allow for the opening of doors, the heat exhaled by persons, lights, etc. (See page 530).

Is there any insulating value in chopped hay and straw, dried grass and leaves, hulls and chaff of grain, and such like ?

In country locations and on the farm they can be used to advantage as packing material for temporary ice houses, fruit houses, etc., but as their life is short they are seldom used in a modern cold storage building.

How are refrigerators sometimes classified ?

As "coolers" having a temperature of 30° or higher; as "holding freezers" having a temperature of 10° or lower; and "sharp freezers" from zero to 20° below zero.

What are freezing chambers ?

They are similar to refrigerating chambers except having more piping they are suitable for quicker and colder work, called "quick freezing" and "sharp freezing."

How are refrigerating and freezing chambers arranged ?

The plans vary greatly, for in some houses alterations have been made where they formerly had large ice bunkers. Sometimes the coils are arranged overhead and on the walls without special precautions against drip.

What necessary "points" in the superintendence of cold storage construction should be observed?

That the house must be air and water-proof; this requires much more care in the way of tight joints and careful workmanship than common; materials should be carefully inspected to see that they are dry and should be kept under cover until used. If the shavings are damp, the bales should be opened and the shavings dried. All filling materials should be properly packed to about the desired density. The joints of water-proof papers should be carefully lapped over two or more inches and also around corners and angles. Sheathing and matched boards should be free from large or loose knots, should be fitted close at corners and angles, and nailed only at bearings. Nails should not be driven through or into sheet material or filled spaces.

What nails should be used?

Cement-coated wire box nails.

How should doors and windows be arranged?

Doors should be of the special cold storage type, and windows treble, and even four and five fold. As few doors and windows as possible should be used.

Should windows be put in cold storage houses?

No, the use of electric light is better.

Should special attention be paid to the doors of cold storage rooms?

They should be carefully constructed, accurately hung and adjusted, well insulated, and the hardware arranged so as to lock tight when the door is closed.

Should cold storage doors open into an ante-room?

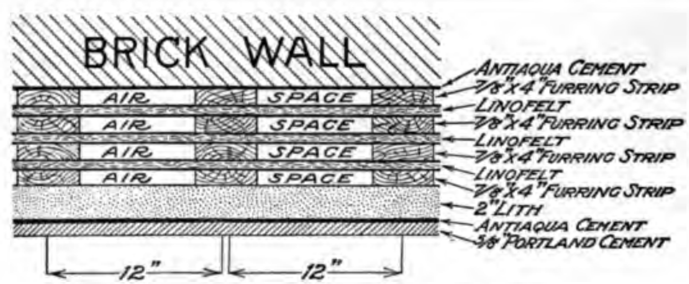
Invariably, for the entrance of warm, moist air into the storage room has a disastrous effect on the goods.

Why is an air lock desirable ?

A lobby or ante-room should be provided for any chambers to be maintained at temperatures below 40° F. It is necessary if the humidity is to be controlled.

What about doors ?

It is most important that entrance doors should be properly constructed and provided with suitable hinges and fasteners to enable them to close air-tight. In some cases additional economy can be effected by the adoption of small hatches or plug doors through which goods can be passed into the chamber or out of it without the necessity of opening the larger entrance door.



Wall insulation with Portland cement finish.

What are the chief advantages to be sought in various building papers ?

To keep out moisture and prevent the circulation of air.

What qualities must they possess ?

They must be odorless, have strength and durability, and should not be brittle.

What are the best papers ?

Those that are saturated with paraffine or that have a central layer of asphalt.

What papers should be avoided ?

Rosin-sized, oiled or tarred papers should not be used on account of their odor ; they will also disintegrate in time.

How should they be applied ?

All joints should be lapped two inches, and, under severe conditions, cemented.

What can be said of the tendency of masonry to absorb moisture ?

In a heavy and driving rain storm of some length, water may penetrate through even a thirteen-inch wall.

How is this difficulty provided for ?

In ordinary building construction by leaving a two-inch air space, which will protect the plaster on the inside wall.

How are basement walls protected ?

They are coated on the outside with pitch, cement or plaster.

What is the common method of protecting the insulation from moisture in masonry walls ?

By coating the walls on the inside with pitch, paraffine, asphalt, etc. Coal tar, on account of the odor, it being liable to taint the goods, is not recommended.

What is the objection to coal tar pitch ?

It hardens too quickly, is brittle, and liable to crack.

What material is preferred ?

Pure asphalt, which is odorless after application. It is not as dense or brittle as pitch, and it has sufficient elasticity so that it does not crack when cooling.

What quality is required ?

A refined quality, such as is obtained from the distillation of Texas or California oils.

Does it harden quickly?

Yes, but not as rapidly as pitch.

What is the difficulty with using asphalt in small cities?

To get a supply of it and find men who can apply it.

How do the natural asphalts come to the market?

In solid form in barrels containing about 50 gallons and weighing from 500 to 550 pounds.

How are the refined asphalts marketed?

In 250 pound barrels containing 25 gallons.

How should care be taken in melting asphalt?

It should not be allowed to boil. This should be specially guarded against as the boiling point is lower than for pitch.

How should asphalt be applied?

By string mops, which is a slow and tedious process because of its heavy consistency and quick cooling. All holes and crevices should be filled up with asphalt as the work proceeds.

How far will asphalt cover when properly melted?

If the walls are dry and the weather warm a gallon will cover about 30 square feet; in cold weather about 20 feet; that is 6000 or 4000 square feet per ton, respectively.

If the surface is rough how much will a ton cover?

Probably not over 3000 square feet.

In what condition should the surfaces be before they are coated?

Free from snow and ice and dry.

Why should the outside of a wall be water-proofed also?

Brickwork full of moisture is a very poor insulator, so that if possible the outside wall should be water-proofed also.

What is the objection to prepared outside coatings ?

They will oxidize and disintegrate in the course of time, and their repair may be neglected.

What is the best outside coating ?

Boiled linseed oil is often used on outside walls and gives very satisfactory results.

What is objectionable in many coatings ?

White and red lead, ground in boiled linseed oil, are more durable coatings than the oil alone but they change the color of the building, while oil gives brick work a darker and richer appearance.

How should it be applied ?

Two or three months after the wall has been finished three coats should be given; afterwards a coat every three or five years will be sufficient.

What is said of its use, price, etc. ?

It is reasonable in price and may be put on the same as paint or varnish.

What is preferable to this except for price ?

Glazed brick or salt-glazed terra cotta blocks, which are water-proof, but very expensive if used as a lining. If used in place of a brick wall the cost is about equal to brick.

Describe one method of insulation approved by Cooper ?

1, A water-proof coating on the inner wall of a wooden building, then, 2, a narrow air space, 3, then ⅞ boards, then 4, three layers of mineral wool slabs, 2 inches thick, slightly tacked and held in place by battens, with water-proof paper between, then, 5, ⅞ inch dressed and matched boards.

[redacted]

Describe another on brick or stone walls ?

The inner wall is first coated with a water-proof cement, put on hot, into which the slabs of insulating material are set. Two or more courses of two or three inch slabs may be used with water-proof cement between them. After setting the slabs another coating of water-proof cement is applied and the surface plastered with Portland cement troweled down smooth.

Is this last an approved method of construction ?

Yes, when finished with Portland cement it is approved as fire-proof by the fire underwriters.

How about the use of charcoal for insulation ?

It is used to a considerable extent in Europe, but not largely in the United States, except in family refrigerators. It is very untidy and as there is an abundance of better materials, it is not considered of importance.

What is another objection to charcoal for insulating purposes ?

It is objected to by insurance companies on account of liability to spontaneous combustion.

What is the insulation value of sawdust ?

It has been largely used by reason of its abundance and cheapness, but as its short life and deteriorating qualities become evident it is supplanted by more indestructible materials.

What are the particular objections to it ?

When dry and clean its insulating value is high, but if it becomes damp it will heat, ferment and rot. This will produce disintegration and it will settle, leaving spaces, and these will become a nesting place for rats and mice. Damp sawdust, too, is liable to make a mouldy and musty condition of the rooms. Nearly all the available sawdust, also, is from green lumber, which renders it unfit for use.

Where is the most satisfactory use for sawdust?

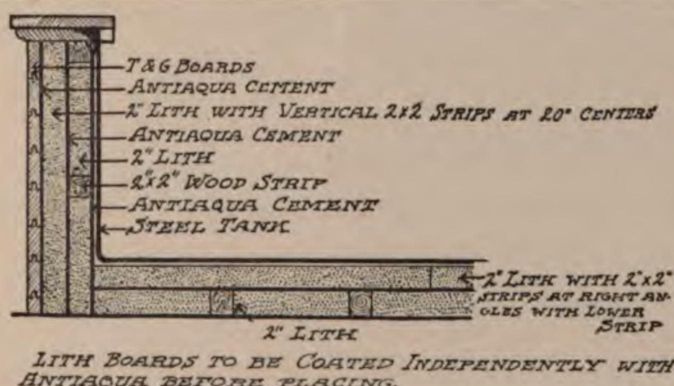
In ice houses storing natural ice, where the house is open to the action of the air, and the sawdust is renewed every year.

Can sawdust be used satisfactorily even between masonry walls?

Even there air and dampness will soon cause deterioration.

What can be said of the value of planing mill shavings?

They will not ferment, rot or settle down like sawdust. They are elastic and clean to handle, and if properly packed, will remain in position for an indefinite period.



Approved method of insulating ice making tank.

What kinds of shavings are preferable?

Those from soft woods as they are lighter and less brittle than hard wood shavings. Odorless woods like spruce, basswood, whitewood, and poplar are most largely used.

How should these shavings be baled for shipment.

Thoroughly dry and free from bark, dirt, and sawdust. They weigh from 80 to 120 pounds per bale, and contain from ten to fifteen cubic feet.

Is wood a good insulator?

Not as much so as has been supposed—six to ten thicknesses have sometimes been used with air spaces between, but it is now thought that this method of construction is too expensive, and not satisfactory from an insulating standpoint.

What can be said of spruce?

It is easy to work, and not so liable to have loose knots or shakes as hemlock.

What about hemlock?

It is cross-grained, rough and splintery, and very likely to split when nails are driven into it. It also has an odor which is an objection to its use for cold storage work.

What can you say of white pine?

White pine may be used if other kinds are not available, but it should be as free from rosin as possible and well seasoned.

Where are these woods used?

For the inside sheathing and finish of the house.

What about sheathing boards?

They should be dressed and matched, as the joint is mcre nearly air-tight.

What is very necessary with all woods?

That they should be thoroughly air-dried; kiln-dried lumber will swell too much.

What may be done when it is necessary to use wood having a slight odor?

It may be given one or two coats of properly prepared whitewash or other deodorizer.

What is hair felt ?

Cattle hair as it comes from the tanner is thoroughly washed and air dried, put through pickers and blowers until all dirt is removed and the hair thoroughly deodorized. It is then put in felting machines and made into sheets 50 feet long, 2 to 6 feet wide, and ¼ to 2 inches in thickness.

What is the value of hair felt as an insulating material ?

It is very high, but the felt is subject to decay; the animal oil contained in the hair becomes rancid and gives off an odor which endangers food products in cold storage.

How can this liability to rancidness be detected ?

By placing a small quantity of hair and water in a glass-stoppered flask and noting the odor after it has been standing a week or thereabouts.

In what other form is hair felt put on the market ?

With a water-proof paper on one side fastened with a water-proof glue.

What is the Cabot quilt ?

That which is made of eel grass, or sea weed as it is often called.

What are its advantages ?

It has great durability, and as it contains a large percentage of iodine it is repellant to rats and vermin.

How have these quilts been made ?

Up to a half inch in thickness, and with water-proof papers on one or both sides.

What are quilt insulators ?

A felt held between two papers and the three parts stitched together.

For what use were these quilt insulators originally designed ?

For deafening purposes in parts of buildings.

What is used for filling purposes in these quilts ?

Hair felt, mineral wool, flax fiber and eel grass; all of which are approved in practice.

How does cork rank as an insulating material ?

Granulated cork is one of the best, for it is odorless, clean, elastic, durable, and does not absorb moisture readily. But like all fillers, except mineral wool, it will not keep out vermin.

How is it obtained ?

It is the waste from cork cuttings.

How should it be used ?

It should be rammed in tightly.

How has cork been made into forms for various uses ?

It has been made into sheets, bricks, etc., by compression in iron moulds at a temperature of 500° F. This liquefies the natural gum of the cork which acts as a binder. Wooden strips for nailing are also inserted in the sheet.

How may these cork sheets be used in another way ?

By cementing them solidly to brick or tile walls.

How are cork bricks used ?

The same as ordinary brick with liquid or asphalt cement as a binder.

What other method of preparing cork board is largely used ?

Granulated cork is mixed with hot asphalt so that each particle is coated; it is then moulded into sheets of varying thickness.

How does this method of manufacture compare with the other method ?

The board is stronger, structurally, and is absolutely waterproof.

How does the efficiency of the two compare ?

The heat which will pass through the baked cork is slightly less than that of the cork which has the asphalt for a binder.

What is mineral wool, and under what names is it known ?

In the United States it is called mineral wool, granite rock wool, and rock cotton; in England, silicate cotton.

How is it made ?

Mineral wool is made from the slag of blast furnaces with limestone added, and the rock wool or rock cotton from granite and limestone.

What is the method of manufacture ?

The slag and rock are first crushed, then fed into furnaces with coke, where it is fused at about 3500° F. The molten slag or lava is then run out at the bottom of the furnace and a high pressure steam blast blows it into a fleece or wool, much resembling sheep's wool, except that the fibers are exceedingly brittle.

How porous is mineral wool ?

It imprisons within itself eleven times its bulk of air.

Does rock or mineral wool contain shot ?

As blown from the furnace, yes.

Is this shot removed ?

As much as four ounces to the pound is often removed. This is done by separators.

Would this shot affect the insulating value ?

It would materially reduce its value as an insulator.

What is the value of mineral wool as an insulator?

Although it is made from a material having a high conductivity, the presence of so much air gives it high rank as an insulator.

What are its advantages?

It is vermin and fire-proof and not liable to decay.

What are its disadvantages?

If packed closer than about twelve pounds to the cubic foot, its brittleness will cause it to disintegrate, which decreases its insulating value. It will absorb moisture quite freely and if it freezes it will expand and break the structure of the material into a granulated mass, which will settle and pack down.

How must mineral wool be packed?

It should be packed lightly, still sufficiently compact to prevent settlement.

What is an important objection against it?

Workmen dislike to handle it for not only will the fibers prick the skin, but the small particles floating in the air are bad for the eyes, nostrils and throat.

How has mineral wool been made in forms?

It is now made into slabs 18 inches by 48 inches, from one-half inch to three inches in thickness, water-proofed, and combined with a flax felt fiber. This material is known under the trade name of Water-proof Lith.

What is the value in heat transmission of Water-proof Lith?

One inch,	6 B. T. U. (British Thermal Units).
Two inch,	3 B. T. U.
Three inch,	2 B. T. U.
Four inch,	1½ B. T. U.
Five	

What is the principal use of the flax fiber quilt ?

It is used almost entirely for the insulation of refrigerator cars and also largely for high grade household ice boxes, etc.

What is the flax fiber quilt commonly called ?

Linofelt.

How do the flax fibers compare with hair in insulating properties.

The flax fiber is composed of hollow tubes very much finer than the hair and therefore containing a greater number of minute confined air spaces, hence the flax is superior.

What methods of heat loss do we need to consider in cold storage ?

At low temperatures the loss by radiation is very small, and we only need to consider convection and conduction in cold storage construction. See pages 45 and 46.

What do all insulation calculations assume ?

That the interior and exterior air is still.

Does the radiation vary with the point of the compass ?

Yes, northern exposure is the greatest.

Explain the loss of heat by radiation ?

It depends on the radiating power of the substance, and the difference in temperature between the surface radiating and the surface receiving the heat, therefore the amount of heat radiated from the outside wall of a chamber depends upon the difference between the temperature of the wall and the surrounding bodies. Good insulation reduces this loss greatly.

Do building materials vary much in respect to radiation ?

They are nearly all alike.

If used, what is one of the chief requirements of wood ?

That it shall be odorless.

How can the radiating power of building materials be estimated?

There is a gain or loss of about ¾ of a heat unit per square foot of surface per hour for one degree difference in temperature.

Upon what does the rate of conduction depend?

It depends, 1, upon the conducting power of the material, 2, upon the difference in temperature between the two exposed surfaces, 3, upon the thickness of the wall, and, 4, upon the area of the surface.

On what does the convection loss depend?

It depends on the difference in temperature of the surface, its nature, and the air in contact with the same. Good insulation will reduce this loss.

What is the best location for cold storage houses?

In the country where the air is pure is best for butter and eggs, and for other goods.

What should be guarded against in all insulations?

No filler should be used in large bulk, because it is liable to settle and leave clear space.

Can mill shavings be kiln dried?

Yes, without opening the bale.

Are insulation computations exact?

All of these calculations are based on conditions which are constantly changing and upon quantities that are never more than approximately correct. A refrigerating engineer must be guided by his experience and judgment, and the plant should have capacity for any contingency which may arise.

How many layers of insulation are placed in refrigerator cars ?

As the result of a series of tests conducted by the railroad systems in 1908, the two thicknesses of insulation or lining which had been usual up to that time have now been increased to four and even five or six layers.

How are the ice bunkers of the most modern refrigerator cars arranged ?

There are ice bunkers at both ends which are filled from hatches on each corner of the roof.

What materials have been used in the past for insulating purposes in refrigerator cars ?

Ashes, wood shavings, cane shavings, chopped straw, mineral wool, peat dust, rice husks, sawdust, pumice stone and charcoal.

Why have they all been found to be of small value ?

Some were of too heavy weight, others were liable to absorb moisture and decay, finally causing the woodwork of the car to rot. In all of them the shaking of the car causes them to settle and leave empty spaces.

To what has this led ?

To the abandonment of all loose materials for it has been found better to leave the insulating space hollow than to use a filling material that is faulty.

What is the comparative value of a refrigerator car provided with board, paper and air spaces, as against one made with modern insulating materials ?

Careful experiments show that the walls of the first car will admit approximately three times the heat that the latter will.

What is the hair felt that is used for insulating purposes ?

Cattle hair that is scraped from hides in abattoirs and tanneries which is then washed and quilted.

What are the objections to its use ?

Although it has a high insulating value, if examined under the microscope a hair will be seen to be a tube partially filled with an animal oil resembling glycerine. While this tube or cylinder is very durable, it is impossible to get rid of the oil by any cleaning process that is commercially practicable, and it soon becomes rancid and decays. This causes disintegration and it becomes liable to taint food products.

Why is flax fiber better than hair felt for insulation purposes ?

The fineness of flax fibers permits them to imprison more minute particles of air than a hair quilt made of the same thickness (see illustration, opposite page 579).

What can be said as to the durability of the flax fiber ?

It is almost the only chemically permanent vegetable fiber in existence. It is not injured by cold or boiling water, and is not affected by any acid solvent.

Why is the insulation of a refrigerator car a more difficult problem than that of a cold storage building ?

1. The car has no machinery to take up the heat that comes in through its walls.

2. The car must, in the course of a several days trip from the Pacific to the Atlantic coast, pass through a constantly varying range of more than 100 degrees of climatic changes; from the summer desert heat of Arizona to the cold of the Northern blizzards.

3. The car is subject to shocks and torsional or twisting strains that are never experienced by a cold storage building.

Why is even the color of the car important ?

A car painted white or silver gray has a tendency to reflect the radiant heat of the sun while dark colors, particularly red, will absorb the heat and increase the ice meltage.

What is the use of the ventilator in a refrigerator car?

A ventilator of proper construction should admit a sufficient volume of air into the car but exclude rain and cinders. It should also admit of easy and quick opening or closing.

How does the greatest damage come to perishable products during transportation?

By the rising of the temperature in the car during the day time and its falling during the night. This constant fluctuation provides ideal conditions for decay.

The temperature of perishable food products should be kept as even as possible whether in refrigerator cars or cold storage warehouses.

What paper is used in connection with the flax fiber quilts?

Lino-Neponset black water-proof paper, weighing ninety pounds to a 1,000 square feet.

How is the flax fiber prepared?

The stalk of the flax plant is a single round cylinder without joints, between two and three feet in height. The woody portion is on the inside. Around this outside is a sheathing of fiber so fine that it compares with the most delicate silks.

This contains, besides the wood and fiber, certain gums and oils. The retting process used in olden times was in fact the rotting of the gums, oils and woody portions so that they were loosed from the fiber, which remained unaffected in the process.

The flax straw for Linofelt is first hackled or broken in a machine which loosens the fiber sheathing from the woody portion or stalk.

The fiber is then carried to the cooking room where it is chemically retted or freed from the chemical gums and oils. It is first picked and combed by special machines, and then is felted by a batting or felting machine into a blanket half an inch in thickness.

PIPE LINE REFRIGERATION.

This section of the work relates to the production of cold as an equivalent for ice at the place where it is needed for use. This has been found to be best accomplished through a street main of wrought iron pipe which is the medium for conveying the liquid that produces the cold in the refrigerator box.

There are two methods in use, one employing chloride of calcium brine, known as the brine system, and the other carrying anhydrous ammonia, under a pressure of several atmospheres, called the direct expansion system.

The first system is hardly practicable for other than short distances, but the anhydrous ammonia system is already in successful operation over lines of several miles in length, and refrigerators along their course are cooled by it as effectively as in a cold storage warehouse.

What should be the temperature of calcium brine used in a street pipe line?

It may leave the station from zero to 10°, according to requirements, and return six degrees higher in temperature.

In a brine pipe line where does the chief interruption to circulation occur?

In the accumulation of air at high points. This must be drawn off and arrangements should be made for doing it at needed intervals.

On what does brine circulation largely depend?

On proper insulation of the supply pipe.

What is to be aimed at in insulation?

A condition in which there is no transfer of heat between bodies of different temperatures.

How is underground insulation arranged?

By putting the pipe in boxes of creosoted plank and filling in with pitch and cork. This gives very satisfactory results.

What is used for especially exposed piping?

Wool, felt or cork, of suitable lengths or half sections.

How may cork be used for brine pipe insulation?

The cork may be packed tight around the pipes and hot pitch or asphalt poured in. It makes a very satisfactory and almost indestructible insulation for an underground pipe line, also for the opening where it goes through masonry walls.

What are some objections to brine pipe circulation?

There is, (1) more or less loss of heat from the brine tank however carefully insulated it may be; (2) it requires considerable power to drive the brine, sometimes a distance of several thousand feet; (3) the brine may also cause in the course of time a rusty and slimy deposit on the interior of the pipes which makes a non-conducting coating; (4) a loss of efficiency possibly as high as 25 per cent; (5) corrosion from electrolysis caused by galvanic action.

What is a distinct disadvantage of a brine pipe service?

That it is impracticable, owing to the power required, to carry the service above the lower floor of a building.

What is an important factor in installing pipe bends?

An easy bend. This reduces the friction very largely.

What weight of pipe is required in a direct expansion pipe line?

What is known as "extra heavy."

What is the winter demand for pipe line refrigeration?

About one-sixth of the summer demand.

What is one of the most important problems presented in pipe line refrigeration?

The variation in load which may come suddenly and without notice.

What system best meets this condition?

The absorption system.

What is the usual method of construction of a direct expansion pipe line?

It consists of three wrought iron pipes laid on saddles in a tile conduit twelve to sixteen inches in diameter.

How are the pipes designated?

A one and one-quarter inch pipe is called the "liquid line," as it carries the outgoing anhydrous ammonia in liquid form. Another pipe, two to four inches in diameter takes the ammonia in gaseous form back to the station and is called the "vapor line." A third pipe is called the "vacuum line." All three pipes run into the refrigerators; the vacuum line is connected with the other two there, and also at manholes which are placed along the line in the streets. In large installations these pipe sizes may be slightly increased.

How are the refrigerators connected with the street line?

Service pipes lead from the street into each box; they are similar to the street pipes except being smaller. Stop boxes are also placed at the curb so that the supply to any particular premises may be shut off when necessary.

What should be the condition of the ammonia in the liquid line?

From the station to the walls of the refrigerator, whatever the distance may be, the ammonia must be under a pressure which exceeds the boiling point of the liquid.

What special advantage does this give ?

As no vaporization takes place in the liquid line and the liquid ammonia is entirely vaporized in the refrigerator piping, no refrigerating work is done in the conduits. It will thus be seen that there are no wastes in this system such as are unavoidable in the distribution of power or heat by steam or electricity.

What is the use of the third line ?

A vacuum is regularly maintained in this line, it being connected with a vacuum pump at the station, hence, in case of fire, or other serious trouble, this line can be connected with that section of liquid line where the trouble is located. The charge can then be rapidly withdrawn and stored in the liquid receiver at the station.

In what other way can the vacuum line be made useful ?

In case it becomes necessary to repair the liquid line or to take on a new customer. Then by means of the connections a part of the liquid line may be "by-passed" and the vacuum line made to serve temporarily as a liquid line.

How is the refrigeration effected in the boxes ?

Where the liquid line enters the refrigerator there is an expansion valve which is operated as described on page 397.

Does pipe line service require any attention on the part of the customer ?

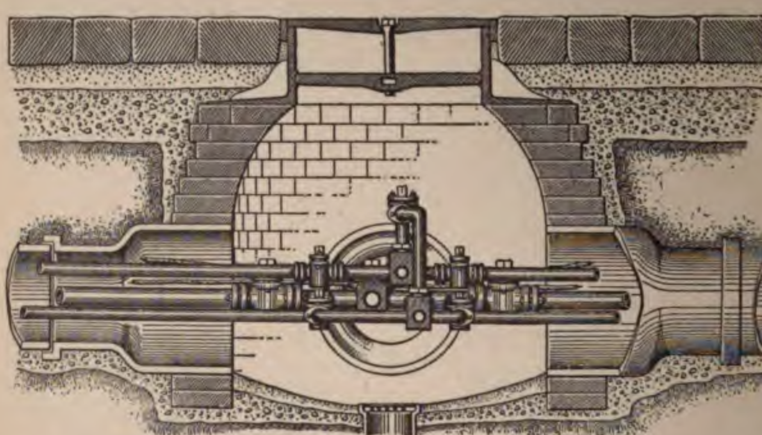
The user of pipe line refrigeration only needs to observe reasonable care in keeping the doors of his boxes closed except when it is necessary to put in or take out goods. In practical operation one or more inspectors from the central station go over the entire line at intervals of a few hours to see that proper temperatures and conditions are maintained in the different boxes.

Why is pipe line service more satisfactory than a small machine?

The latter, except in combination with other machinery needed for elevators, electric lights, etc., is not an economical way to obtain refrigeration, and neither the process of producing cold by mechanical means nor the apparatus it requires can be so simplified as to work well without skilled oversight.

At what temperature does the ammonia enter the outgoing pipe line?

Not much above that of the surrounding earth; the tendency is to fall somewhat en route, which is an advantage.



Section of Manhole designed by John E. Starr for the St. Louis Refrigerating & Cold Storage Company. This direct expansion ammonia line is six miles in length, and has been in successful operation since 1900.

What is the pressure carried in the return pipe line?

It varies from, perhaps, 25 pounds per square inch at the end of the line down to about 5 pounds at the station.

How is it possible to make long continuous coils of pipe?

By electric, oxy-acetylene or thermit welding.

EMERGENCIES AND ACCIDENTS.

Few subjects can more usefully employ the attention and study of engineers than the proper treatment and first remedies made necessary by the peculiar and distressing accidents to which persons are liable who are employed in or around a steam or refrigerating plant.

The prompt cleaning and dressing of slight accidental wounds gives great relief to the sufferer and renders later medical attention more effective. In many cases nothing more may be needed, but neglected or delayed treatment of simple injuries often leads to very serious consequences.

These and many other things of a like nature call for a cool head, a steady hand and some practical knowledge of what is to be done. In the first moments of sudden disaster, of any kind, the thoroughly trained engineer is nearly always found, in the confusion incident to such a time, to be the one most competent to advise and direct the efforts made to avert the danger to life, limb or property, and to remedy the worst after effects.

There are no hard and fast rules to lay down for all such occasions, but in the operation of a refrigerating plant there will arise events which must call for the coolness and readiness of resource on the part of the operating engineer, as in the case of an accident to the ammonia system, causing an outflow of gas, especially on the high pressure side; and in such exigencies there will be no time for prevision or reflection; the matter must be attended to instantly.

To meet this responsibility is worth much previous preparation, so that the best things under the circumstances may be done quickly and efficiently. To this end the following advice is given relating to the most common accidents that are likely to happen, in spite of the utmost exercise of care and prudence.

What should invariably be done before breaking an ammonia joint ?

The pressure should be removed. (See pages 82 and 500).

What must be done first when an accident happens to the high pressure side of an absorption system, causing an escape of gas?

It is absolutely necessary to relieve the pressure at once; stop the ammonia pump and close the steam valve to the generator. Then open the expansion valve and the poor liquor valve to the absorber. After this, one must be governed by circumstances.

In case of a dangerous escape of ammonia what should one do ?

Now, as the specific gravity of ammonia is only about half that of air it has a tendency to rise and one exposed to the fumes should drop quickly as near the floor as possible until he can escape upon his hands and knees, or by bending over.

What is to be done when a person has inhaled ammonia fumes ?

A man that is overcome by the fumes of ammonia can do nothing for himself, and needs help. If he is conscious, sucking a lemon or drinking diluted vinegar is a good starter. The vinegar must be pure cider vinegar, with acetic acid as the active principle, not the ordinary commercial vinegar on the market, which is a sulphuric acid product, and not effective in neutralizing ammonia. Acetic acid is volatile, and should be placed in an open vessel where it can be breathed deeply by the patient.

Ammonia fumes will quickly strangle a man, and will temporarily destroy the sight. Lay an unconscious man in the open air and give from a half pint to a pint of warm milk. This is good treatment for one overcome by any kind of gas.

What precaution should always be taken in case of a fire or serious leak ?

A suitable helmet or mask should always be worn.

Should helmets always be kept at hand ?

To be thoroughly prepared for leaks and breaks, every plant where ammonia is used should be equipped with a helmet ready for use at any moment. This will protect the eyes, nose and mouth long enough to enable the engineer to make temporary repairs.

What may be used as a substitute in case of necessity ?

A cheaper way, and one which will answer in minor accidents, is to keep three or four sponges with strings attached so they can be tied over the mouth and nose. A bottle of pure cider vinegar kept handy to the sponges is the rest of the life-saving apparatus. Soak the sponge in the vinegar and it will neutralize the ammonia so it can be safely breathed for a while. There is no protection for the eyes in this method, however.

How should the patient's eyes be treated ?

A few drops of a one per cent solution of boric acid is good. The eyes should be opened and shut several times to thoroughly distribute the solution.

What is a good dressing for the flesh ?

Equal parts of lime water and raw linseed oil is the best dressing for flesh that has been injured by ammonia. This liniment is usually called carron oil from its first use at the Carron Iron Works in Stirlingshire, Scotland.

Why is it a good plan to have some head of water available by means of hydrants in various parts of the building ?

Not only for fire purposes but also to absorb ammonia in case of a leak.

If a small leak is causing trouble, a piece of waste or cloth soaked in water and tied over it will absorb the ammonia for a time. If you are compelled to work over or around an ammonia leak of dangerous size, let an assistant spray a steady stream

of water on it with a hose. A 2½-inch hose with a 1¼-inch fire nozzle will take care of a large leak if the stream is sprayed directly on the orifice where the ammonia is escaping. When working around bad leaks it is best to use the vinegar-soaked sponge, even when water is being sprayed on the spot.

How should the workmen be made familiar with the use of water in emergencies ?

It is a good idea for an engineer to drill the whole crew into the habit of playing a stream of water on a leak of ammonia. If the habit is formed, and every man around the plant knows that a stream from a hose will control a leak so that access can be had to it for repair work, there will come a time when the engineer will congratulate himself on his foresight. It is a rare occurrence when a break cannot be kept from doing serious injury if the water cure is given promptly.

What is a good tool or device for closing a valve wheel from a few feet distance in case of accident ?

There is a device which comes in good use if a gauge glass breaks. It is merely a light wooden rod, about ten feet long, with a handle on one end and the other fitted with a set of prongs so they will catch hold between the spokes of the valve wheel and enable one to turn the wheel from a safe distance.

When may ammonia become explosive ?

If mixed with about twice its volume of air in a closed room, and other conditions are favorable for an explosion, the mixture may ignite and cause an accident.

What course of action is advisable in case of fire ?

Ammonia is not, strictly speaking, combustible, and in the early stages of a fire it would have a tendency to smother it, so that the engineer would have to consider what would be the best course under the circumstances. In case the fire got beyond control the intense heat would doubtless cause a chemical

change of the ammonia into hydrogen and nitrogen, thus, probably causing an explosion, and even if it did not the hydrogen would burn. It might be advisable to allow the ammonia to escape whenever it is deemed better policy to stand the loss of the ammonia than to run the risk of a fire. If the latter should occur the ammonia would be lost, and that too most likely at a temperature high enough to make it share in the conflagration, while when allowed to escape, as long as the fire is low, it may help to stifle the same or extinguish it altogether.

What are the peculiar features of burns and scalds?

Burns are produced by heated solids or by flames; scalds are produced by steam or a heated liquid. The severity of the accident depends mainly, 1, on the intensity of the heat of the burning body, 2, the extent of surface injured, and, 3, the vitality of the parts involved in the injury, thus: a person may have a finger burned off with less danger to life than from a severe scald on his back.

The immediate effect of scalds is generally less violent than that of burns, as fluids are incapable of acquiring such high temperatures as some solids; but since they flow with great facility, they may affect large surfaces.

What remedies should be used on a burn?

The free use of soft soap or vaseline upon a fresh burn will remove the irritation from the flesh in perhaps less than half an hour. If the burn be severe, after relief from the pain, use linseed oil and then sift upon it wheat flour. When this is dried repeat the oil and flour until a complete covering is formed, and when it falls off, a new skin will have grown, possibly without a scar.

In burns with lime, soap lye, or any caustic alkali, wash abundantly with water (do not rub), and then with weak vinegar, finally apply boracic acid ointment.

It would be well to always keep ready mixed a preparation for burns; in fact a previous readiness for an accident may rob it of half its ill effects.

What supplies should always be kept on hand in a case for accidents?

One bottle of cider or wine vinegar.
One bottle of lime water.
One bottle of raw linseed oil.
One pint bottle of tincture of arnica.
One quart bottle of 2% solution of carbolic acid.
One pint bottle of 1% solution of boric acid.
One small jar of boric or boracic acid ointment, 5%.
One roll of absorbent cotton.
One package of antiseptic gauze.
One roll of adhesive plaster.
One box safety pins.
One pair dressing scissors.
One pair dressing forceps.
Several soft sponges.
Two clean basins, for water.

How may clothing be removed when necessary?

To get at a broken limb, or rib, the clothing must be removed, and it is essential that it be done without injury to the patient; the simplest plan is to rip up the seams of such garments as are in the way. Boots and shoes should be cut off when necessary.

How may an injured person be aided if he is able to walk?

Where an injured person can walk he will get much help by putting his arms over the shoulders and round the necks of two others.

A seat may be made with four hands and the person may be thus carried and steadied by clasping his arms around the necks of his bearers.

If only one person is available and the patient can stand up, let him place one arm round the neck of the bearer, bringing his hand on and in front of the opposite shoulder of the bearer.

What may be done if he is unable to walk?

In case of an injury where walking is impossible, and lying down is not absolutely necessary, the injured person may be seated in a chair, and carried; or he may sit upon a board, the ends of which are carried by two men, around whose necks he should place his arms so as to steady himself.

How may a temporary stretcher be made and used?

To carry an injured person by a stretcher (which can be made of a door, shutter, or settee—with blankets or shawls or coats for pillows) three persons are necessary. In lifting the patient on the stretcher it should be laid with its foot to his head, so that both are in the same straight line; then one or two persons should stand on each side of him, and raise him from the ground, slip him on the stretcher; this to avoid the necessity of any one stepping over the stretcher, and the liability of stumbling. If a limb is crushed or broken, it may be laid upon a pillow with bandages tied around the whole (i. e., pillow and limb) to keep it from slipping about. In carrying the stretcher the bearers should "break step" with short paces; hurrying and jolting should be avoided, and the stretcher should be carried so that the patient may be in plain sight of the bearers.

What should be done in case of frost-bite?

No warm air, warm water, or fire should be allowed near the frozen parts until the natural temperature is nearly restored; rub the affected parts gently with snow or snow water in a cold room; the circulation should be restored very slowly; and great care must be taken in the after treatment.

How is a refrigeration plant regarded by fire underwriters ?

Special hazards of mechanical refrigeration are few and easily cared for. The principal one is that of explosion, as from rupture of a cylinder or bursting of a connection due to excess pressure, which is always present. The working pressure of an ammonia compression system, running from 125 to 170 pounds and those of a carbonic acid system, running from 300 to 1,000 pounds, necessitates specially constructed joints and fittings. A very important part of the apparatus to be guarded is the discharge valve between the compressor and condenser which should never be closed except for making repairs. The hazards connected with the steam end of the compressors are those of any ordinary steam engine.

How do the Underwriters regard the hazard by fire ?

There has been a great deal of discussion as to whether ammonia gas is inflammable or not. There is little doubt that accidents have happened by the explosion of a jet of ammonia when mixed with vaporized oil, escaping from a leak and striking an open gas flame. It is also possible, that ammonia gas may contain impurities which are inflammable. In some types of machines oil is injected into the cylinders of the compressor at every stroke in order to cool the same. This introduces some hazard, but probably not an excessive one. The hazard in an absorption system is very much less than that in a compression system. The systems using carbon dioxide and sulphur dioxide appear to present no hazard except that incident to moving machinery and the possibility of overpressure and explosion.

What are the recommendations of the Fire Underwriters as given in a detailed report ?

(1). It is desirable that compression machinery in general, should be installed in such a way that an explosion from overpressure could not cause damage outside of the room in which it occurs. For instance, it would be better to install apparatus of this kind in a small one-story building communicating, if

necessary, with the engine room or boiler room, rather than to locate it in the same room where its explosion might wreck the engines and boilers.

(2). It is desirable that, wherever possible, relief valves should be arranged in the system to take care of over-pressures, special precautions being taken to prevent freezing of such valves.

(3). It is important in an ammonia system that an automatic valve of suitable design be provided in the exhaust pipe of the compressor to prevent the escaping of the entire charge of the ammonia should there be trouble at the compressor.

(4). All gauge glasses in ammonia systems should be provided with automatic ball stops which will act in the event of breaking glass.

(5). Open flames should never be permitted near an ammonia compression machine.

(6). It is recommended that wherever in any system graphite can be used as a lubricant in compressor cylinders that it be done. This especially applies to air compressors used in dense air systems and for air compression for purposes other than refrigeration, as the temperature of the compression cylinders rises in some air systems to a point where inflammable vapors may be generated from lubricating oil.

(7). The use of light petroleum distillates, ether and other similar fluids or gases, as refrigerants, is extremely hazardous even with all precautions taken.

(8). The storage of any liquefied or highly compressed gas, whether inflammable or not, in steel tubes or other receptacles, is hazardous, more to life and limb than by reason of fire. A comparatively moderate increase in temperature in one of these cylinders or drums might cause it to explode. This is especially true of carbon dioxide. Tubes or containers of all of these liquids or gases should be kept in a safe place where they will not be exposed to heat, either artificial or natural.

Give a description of the National Smoke and Ammonia Helmet.

It consists of a flexible helmet of thin fire-proof fabric connected by flexible metallic tubing to a reservoir, charged either with compressed air or oxygen and fitted with proper valve control mechanism. (See page 650).

How is the helmet worn ?

As it is made of soft material it may be put on by any person without adjustment, a tight, but comfortable fit, being secured around the neck by a lining of lamb's wool which acts as an absorbent for moisture from the breath and foul air outlet.

Does the use of this helmet obstruct the sight or hearing ?

The sense of hearing is only slightly dulled, and the flexibility of the headpiece enables the wearer to turn his head in any direction and see where he is stepping. The eye glasses may be cleaned from condensation or dirt by means of a slide which has a wiper on the inside of the glass, although it is moved from the outside.

Describe the reservoir.

It is of pressed steel of ample strength for the pressure required, and is suspended from the shoulder by a strap so that its position can be shifted as may be necessary. The air supply will last half an hour or longer depending on the exertion of the wearer. It is regulated by a valve which is in plain sight, and the pushing of a small button near an air gauge shows the condition of the air supply at any time.

How is the air valve regulated ?

When the air valve is opened an automatic locking device closes it when the proper air supply is admitted to the helmet, which averts any waste or possibility of the wearer, in a moment of great excitement, opening the valve too wide.

This locking arrangement may be easily released, however, in case violent exertion at any time renders an extra air supply necessary.

How are the "Eveready" Smoke and Ammonia Helmets made?

They are constructed of calf skin with a reinforced steel frame and are made tight about the neck by a flexible steel spring.

How is the air supplied?

There is no pumping of air, consequently no high pressure gauges or valves are necessary, but the air in the helmet is kept automatically pure by passing through a chamber containing oxygen as it is inhaled and exhaled. (See page 650).

How is the oxygen supplied?

From a prepared cartridge which is inserted in the purifying chamber, and which can be easily replaced when necessary.

Describe the Peerless Head Protector.

It is made of flexible leather and a frame work protects the head from danger of falling objects. A fireproof flexible metal tubing connects the headpiece with the air supply.

How is the air supply carried?

In a steel cylinder which is held in place on the back or sides, as desired, by one strap thrown over the shoulder and another around the waist.

How is the air supply regulated?

The steel cylinder, which carries 150 pounds air pressure, is provided with an intake valve at one end and a reducing valve at the other; the latter is regulated to supply sufficient air to last an hour.

ICE FROM RAW WATER.

The efforts of mechanical engineers to decrease the cost of production without reducing the quality of a certain product have found expression in the ice making industry by a study of the possibility of doing away with the complication and expense of the distilling apparatus, and the freezing of water just as it is drawn from springs, wells or water mains, that is "raw" water, as it is called in the refrigerating industry. Improved methods of sterilizing and filtering water have contributed to the solution of this problem, and besides the plate system already mentioned (page 451), two or three other methods have attracted considerable attention and merit at least a brief description.

If water is pure enough to be fit for drinking, why cannot it be frozen in cans just the same as distilled water?

As it contains air it is impossible to freeze it from all sides, as in a can, without obtaining a white core in the center.

How has this been remedied to some extent?

By agitating the water in the cans by various means, especially by a jet of compressed air from the bottom.

Describe the Hume system.

Large cans, four times the cross section of a 300 pound can are used, and the air is introduced by a pipe running down the center of the can and having small openings at the bottom. When the cake is frozen, the can is raised from the tank and thawed out as usual; a saw then cuts it into four cakes of standard size. This releases the air pipe in the center and the sawing process practically does away with the small core which surrounds it.

What is the Hill-Ray process?

This is practically the plate system with improvements which reduce the original cost and expense of harvesting the product. The ice is frozen on iron plates which are bolted on pipes welded together so as to form continuous coils.

Ammonia is expanded through these coils, and is succeeded by bringing hot gas from the compressor in the thawing off process.

How is the ice removed from the plate?

Attached to the plate at right angles are hollow cross cuts which are frozen into the ice. These may be placed any distance apart according to the width of cake desired.

When the ice is thick enough these cross cuts are removed by introducing a small amount of hot water into each one. The hot gas from the compressor now releases the ice from the iron plate and it is raised from the tank in the usual manner.

What is the Jewell system?

This system does away with the ice tank entirely, the cans being made double or jacketed and cold brine being circulated through this jacket until the cake is frozen.

How is the cake kept clear?

A non-freezing zone about six inches in depth is maintained in the bottom of the can, and an air nozzle placed in the bottom of the center of this zone, supplied with compressed air of about three pounds pressure, keeps up a constant agitation of the water in the can until it is nearly frozen.

It is well known to refrigerating engineers that the formation of ice crystals expels the impurities in suspension, and even a large proportion of those in solution, which are thus forced to the center and fall to the lower part of the can.

The water from the core, and bottom part of the can is now drawn off and replaced by water from the forecooler when the cake is allowed to freeze solid.

How is the filling of the cans and the removal of the impure water expedited ?

The cans are arranged in batteries or units of, say, fifty, and so connected up that the opening of one valve permits their filling simultaneously, while another valve drains them by gravity just as rapidly.

How is the ice taken out of the can ?

The temperature of the circulating brine is raised until the cake of ice thaws from the sides of the can when it is raised in the usual manner.

What are important advantages of the Jewell process ?

There are no connections of the air, brine, and drain lines to be broken so that the whole system always remains intact. It is also claimed that the first cost is less than that of a plate plant and that ice is frozen much more quickly.

How is the manufacture of ice from raw water largely aided by efficient filters ?

The Buhring Purifier has been found to give very good results with this method of ice making. It is a moulded carbon block, made in Germany, and varying in density for the duty required. It is placed in a porcelain-lined shell and packed with loose granulated carbon and asbestos. The water passes first through the loose material, leaving most of the coarser impurities, then through the carbon block which retains all the finer sediment. The cylinders which contain these blocks are comparatively small and are arranged in series or batteries, so that they occupy but little room. (See page 650). This Purifier deodorizes the water as well as filters it at a cost as low as three cents per ton of ice manufactured. It is in use in many of the most modern New York hotels where it has not been found necessary to renew the carbon block oftener than once a year.

Absorption Refrigeratin

Chief E

For 24 hours ending at....

TE

Time	DEHYDRATOR		ABSORBER				EXCHANG		
	Gas In	Gas Out	Weak Aqua In	Strong Aqua Out	Water In	Water Out	Weak Aqua In	Weak Aqua Out	St Aq
7 a. m.									
11 a. m.									
3 p. m.									
7 p. m.									
11 p. m.									
3 a. m.									
Average									

PRESSURES

Time	GENERATOR			RECEIVER	BRINE COOLER	ABSORBER	BRINE		
	Ammonia	Steam	Exhaust steam	Ammonia	Ammonia	Ammonia	Low	High	
2 a. m.									
4 "									
6 "									
8 "									
10 "									
Noon									
2 p. m.									
4 "									
6 "									
8 "									
10 "									
Mid-night									

ICE MAKING

Time	Cans Pulled	Tons Harvested	Tons to Kitchen	

TONNAGE OF MACHINE

Time	
	Rev. of Brine Pump X Average Range X Factor = Tons Refrigeration
	H. P. Brine X X =
	L. P. " X X =
	Total Tonnage of Refrigerating Machine
	Remarks

nt.	Plaza Hotel, N. Y.
s Daily Log.

............................19....

TURES

	CONDENSERS			BRINE						
				HIGH PRESSURE			LOW PRESSURE			
Strong qua Out	Water In	Water Out	Range	In	Out	Range	In	Out	Range	Ice Tank

METER READINGS

OILER	Time	WATER TO MACHINE		Time	CONDENSED STEAM FROM GENERATOR	
team		Final			Final	
		Previous			Previous	
		Cu. Ft. used			Cu. Ft. used	

BRINE AND AMMONIA PUMPS

	LOW PRESSURE	HIGH PRESSURE	AMMONIA PUMPS
Final			
Previous			
Rev.			

STRENGTH OF AQUA AMMONIA AND BRINE

	STRONG AQUA			WEAK AQUA			BRINE
Time	Deg. Beaume	Temp't	Corrected to 60o F.	Deg. Beaume	Temp.	Corrected to 60o F.	at 60o F.

ns to Restaurant	Tons to Bars

Date...

REFRIGERATING ENGINEERS

ON DUTY

Time on	Time off	Name

USEFUL NUMBERS FOR RAPID APPROXIMATION

537 lbs. per cu. ft.=wt. of copper.
450 lbs. per cu. ft.=wt. of cast iron.
485 lbs. per cu. ft.=wt. of wrought iron.
708 lbs. per cu. ft.=wt. of cast lead.
490 lbs. per cu. ft.=wt. of steel.
1 gal. water=8⅓ lbs.=231 cu. in.
1 cu. ft. water=62½ lbs.=7½ gals.
1 lb. water=27.8 cu. in.=1 pint.

12 × wt. of pine pattern=iron casting.
13 × wt. of pine pattern=brass casting.
19 × wt. of pine pattern=lead casting.
12.2 × wt. of pine pattern=tin casting.
11.4 × wt. of pine pattern=zinc casting.
1 cubic foot anthracite coal=54 lbs.
40 to 43 cubic feet anthracite coal=1 ton.
49 cubic feet bituminous coal=1 ton.

Feet	×	.00019	=miles.
Yards	×	.0006	=miles.
Links	×	.22	=yards.
Links	×	.66	=feet.
Feet	×	1.5	=links.
Square inches	×	.007	=square feet.
Circular inches	×	.00546	=square feet.
Square feet	×	.111	=square yards.
Acres	×	4840.	=square yards.
Square yards	×	.0002066	=acres.
Cubic feet	×	.04	=cubic yards.
Cubic inches	×	.00058	=cubic feet.
U. S. bushels	×	.046	=cubic yards.
U. S. bushels	×	1.244	=cubic feet.
U. S. bushels	×	2150.42	=cubic inches.
Cubic feet	×	.8036	=U. S. bushels.
Cubic inches	×	.000466	=U. S. bushels.
U. S. gallons	×	.13368	=cubic feet.
U. S. gallons	×	231.	=cubic inches.
Cubic feet	×	7.48	=U. S. gallons.
Cylindrical feet	×	5.878	=U. S. gallons.
Cubic inches	×	.004329	=U. S. gallons.
Cylindrical inches	×	.0034	=U. S. gallons.
Pounds	×	.009	=cwt. (112 lbs.).
Pounds	×	.00045	=tons (2,240 lbs.).
Cubic feet water	×	62.5	=lbs. avdps.
Cubic inches water	×	.03617	=lbs. avdps.
Cylindrical feet of water	×	49.1	=lbs. avdps.
Cylindrical inches of water	×	.02842	=lbs. avdps.
U. S. gallons of water	÷	13.44	=cwt. (112 lbs.).
U. S. gallons of water	÷	268.8	=tons.
Cubic feet water	÷	1.8	=cwt. (112 lbs.).
Cubic feet water	÷	35.88	=tons.
Cylindrical feet of water	÷	5.875	=U. S. Gallons.
Column of water 12 in. high, 1 in. diam.			=.34 lbs.
183,346 circular inches			=1 square foot.
2,200 cylindrical inches			=1 cubic foot.
French meters	×	3.281	=feet.
Kilogrammes	×	2.205	=avdps lbs.
Grammes	×	.0022	=avdps. lbs.

The friction of water in pipes is as the square of its velocity.

Doubling the diameter of a pipe increases its capacity four times.

In tubular boilers 15 square feet of heating surface are equivalent to one horse power; in flue boilers, 12 square feet of heating surface are equivalent to one horse power; in cylinder boilers, 10 square feet of heating surface are equivalent to one horse power.

One square foot of grate will consume on an average 12 lbs. of coal per hour.

Consumption of coal averages 7½ lbs. of coal, or 15 lbs. of dry pine wood, for every cubic foot of water evaporated.

The ordinary speed to run steam pumps is at the rate of 100 feet piston travel per minute.

Freezing Mixtures

Composition of Freezing Mixtures in Parts by Weight	Reduction of Temperature in Deg. Fahr.		Amount of Fall in Deg., Fahr.
	From	To	
Snow 2 parts; common salt 1 part		— 5	
Snow 5; common salt 2; ammonium chloride 1		—12	
Snow 14; common salt 10; ammonium chloride 5; potassium nitrate 5		—18	
Snow 12; common salt 5; ammonium nitrate 5,		—25	
Ammonium chloride 5; potassium nitrate 5; water 16	. 50	+ 4	46
Ammonium nitrate 1; water 1	. 50	+ 4	46
Ammonium chloride 5; potassium nitrate 5; sodium sulphate 8; water 16	+50	+ 4	46
Sodium sulphate 5; dilute sulphuric acid 4	+50	. 3	47
Sodium sulphate 8; hydrochloric acid 9	+50	0	50
Sodium nitrate 3; dilute nitric acid 2	+50	— 3	53
Ammonium nitrate 1; sodium carbonate 1; water 1	+50	— 7	57
Sodium sulphate 6; ammonium chloride 4; potassium nitrate 2; dilute nitric acid 4	+50	—10	60
Snow 8; dilute sulphuric acid 3; dilute nitric acid 3	—10	—56	46
Sodium sulphate 6; ammonium nitrate 5; dilute nitric acid 4	+50	—14	64
Snow 1; common salt	+32	0	32
Snow 3; dilute sulphuric acid 2	. 32	—23	55
Snow 3; hydrochloric acid 5	+32	—27	59
Snow 7; dilute nitric acid 4	+32	—30	62
Snow 4; calcium chloride 5	. 32	—40	72
Snow 8; calcium chloride 5	+32	—40	72
Snow 2; calcium chloride, crystalized 3	+32	—50	82
Snow 3; potassium 4	. 32	—51	83
In the Following Mixtures Materials Must be Previously Cooled:			
Snow 3; calcium chloride 4	+20	— 4	24
Sodium phosphate 5; ammonium nitrate 3; dilute nitric acid 4	0	—34	34
Snow 3; dilute nitric acid 2	0	—46	46
Snow 1; calcium chloride, crystalized 2	0	—66	66
Snow 2; dilute sulphuric acid dilute nitric acid 1	—10	—56	46
Sodium phosphate 9; dilute nitric acid 4	+50	—12	62
Snow 2; calcium chloride 3	—15	—68	53
Snow 12; common salt 5; ammonium nitrate 5	—18	—25	7
Snow 1; dilute sulphuric acid	—20	—60	40
Sodium Phosphate 3; ammonium nitrate 2; dilute mixed acid	—34	—50	16
Snow 1; calcium chloride 3	—40	· 73	33
Snow 2; calcium chloride, crystalized 3	—40	—73	33
Snow 8; dilute sulphuric acid 0	—68	—91	23

When no snow is to be had, finely crushed or grated ice will answer.
Dilute acid is 1 part strong commercial acid and 9 parts water.

Comparison of Thermometers

Fahr. $=32+\frac{9}{5}$ Cent. $=32+\frac{9}{4}$ Reau.

Freezing point on Fahrenheit scale is +32°; Boiling point 212°.
" " Centigrade " 0° " " 100°.
" " Reaumur " 0° " " 80°.

Of water at sea level at normal Barometer pressure (29.9 in.)

The "Absolute Zero" of temperature denotes that condition of matter at which heat ceases to exist. At this point a body would be wholly deprived of heat and a gas would exert no pressure.

The Absolute Zero on the Fahrenheit scale is about 461° below Zero.
" " " " Centigrade " " 274° " "
" " " " Reaumur " " 219° " "

Cent.	Reau.	Fahr.	Cent.	Reau.	Fahr.	Cent.	Reau.	Fahr.
—40	—32.0	—40.0	21	16.8	69.8	62	49.6	143.6
—38	—30.4	—36.4	22	17.6	71.6	63	50.4	145.4
—36	—28.8	32.8	23	18.4	73.4	64	51.2	147.2
—34	—27.2	—29.2	24	19.2	75.2	65	52.0	149.0
—32	—25.6	—25.6	25	20.0	77.0	66	52.8	150.8
—30	—24.0	—22.0	26	20.8	73.8	67	53.6	152.6
—28	—22.4	—18.4	27	21.6	80.6	68	54.4	154.4
—26	—20.8	—14.8	28	22.4	82.4	69	55.2	156.2
—24	—19.2	—11.2	29	23.2	84.2	70	56.0	158.0
—22	—17.6	—7.6	30	24.0	86.0	71	56.8	159.8
—20	—16.0	—4.0	31	24.8	87.8	72	57.6	161.6
—18	—14.4	—0.4	32	25.6	89.6	73	58.4	163.4
—16	—12.8	+3.2	33	26.4	91.4	74	59.2	165.2
—14	—11.2	6.8	34	27.2	93.2	75	60.0	167.0
—12	—9.6	10.4	35	28.0	95.0	76	60.8	168.8
—10	—8.0	14.0	36	28.8	96.8	77	61.6	170.6
—8	—6.4	17.6	37	29.6	98.6	78	62.4	172.4
—6	—4.8	21.2	38	30.4	100.4	79	63.2	174.2
—4	—3.2	24.8	39	31.2	102.2	80	64.0	176.0
—2	—1.6	28.4	40	32.0	104.0	81	64.8	177.8
0	0.0	32.0	41	32.8	105.8	82	65.6	179.6
+1	+0.8	33.8	42	33.6	107.6	83	66.4	181.4
2	1.6	35.6	43	34.4	109.4	84	67.2	183.2
3	2.4	37.4	44	35.2	111.2	85	68.0	185.0
4	3.2	39.2	45	36.0	113.0	86	68.8	186.8
5	4.0	41.0	46	36.8	114.8	87	69.6	188.6
6	4.8	42.8	47	37.6	116.6	88	70.4	190.4
7	5.6	44.6	48	38.4	118.4	89	71.2	192.2
8	6.4	46.4	49	39.2	120.2	90	72.0	194.0
9	7.2	48.2	50	40.0	122.0	91	72.8	195.8
10	8.0	50.0	51	40.8	123.8	92	73.6	197.6
11	8.8	51.8	52	41.6	125.6	93	74.4	199.4
12	9.6	53.6	53	42.4	127.4	94	75.2	201.2
13	10.4	55.5	54	43.2	129.2	95	76.0	203.0
14	11.2	57.2	55	44.0	131.0	96	76.8	204.8
15	12.0	59.0	56	44.8	132.8	97	77.6	206.6
16	12.8	60.8	57	45.6	134.6	98	78.4	208.4
17	13.6	62.6	58	46.4	136.4	99	79.2	210.2
18	14.4	64.4	59	47.2	138.2	100	80.0	212.0
19	15.2	66.2	60	48.0	140.0			
20	16.0	68.0	61	48.8	141.8			

Mechanical Refrigeration—Rates from Principal Cold-Storage Houses

TABLE OF GENERAL STORAGE

Substance	Conditions Kind of Package or Amount	Best Temperatures, Degrees	Fraction of a Month	First Month	Each Succeeding Month	For the Season	Season Ends	General Season is from May to May
	Transient small lots	32 to 38	$0.00⅛	$0.00¼	$0.00½	. . . .	. . . .	Gross weight
	500 to 1000 pounds	32 to 38	. . . .	. . . .	. . . .	$0.00¾	. . . .	Gross weight
	10,000 pounds	32 to 38	. . . .	. . . .	. . . .	.00⅝	. . . .	Gross weight
Butter	Season rates before the 15th of August	32 to 38	. . . .	. . . .	. . . .	.01	May 1	Gross weight
	After 15th of August to 1st of October	32 to 38	. . . .	. . . .	. . . .	.00¾	May 1	Gross weight
	After 1st of October	32 to 38	. . . .	. . . .	. . . .	.00½	May 1	Gross weight
	Carried over one season	32 to 38	. . . .	. . . .	. . . .	.03¼	. . . .	Net weight
	Carried over two seasons	32 to 38	. . . .	. . . .	. . . .	.04¼	. . . .	
	60-pound boxes	33	. . . .	.12	. . . .	. . . .	. . . .	Per box
Cheese	35-pound boxes	33	. . . .	.08	. . . .	. . . .	. . . .	Per box
	18-pound boxes	33	. . . .	.05	. . . .	. . . .	. . . .	Per box
	Per pound	33	. . . .	. . . .	.00⅛	.00⅝	Dec. 1	Gross weight
	30 dozen cases	32 to 34	. . . .	. . . .	.15	. . . .	. . . .	Per case
Eggs	36-dozen cases	32 to 34	. . . .	. . . .	.18	. . . .	. . . .	Per case
	Per dozen	32 to 34	. . . .	.00½	.00½	.02½	April 1	Same rate for part of season
	In barrels	32 to 34	. . . .	. . . .	.40	. . . .	. . . .	
Dried fruit	Per flour barrel	36	. . . .	. . . .	. . . .	1.25	Nov. 1	
Apples, peaches	Per sugar barrel	36	. . . .	. . . .	. . . .	1.60	. . . .	
Pears, cherries	Sacks, per pound	36	. . . .	. . . .	. . . .	.00⅝	. . . .	Gross weight
Berries, etc.	Per pound	36	. . . .	.00¼	. . . .	.00¾	. . . .	
Fresh fruit	In boxes	36	. . . .	.05	. . . .	. . . .	. . . .	Per cubic foot
	In lots of 50 barrels and upwards	28 to 32	. . . .	.20	. . . .	1.00	July 1	
Apples	500 barrels	28 to 32	. . . .	.20	.15	. . . .	. . . .	
	1000 or over	28 to 32	. . . .	. . . .	.15	. . . .	. . . .	
Peaches	Per crate	. . . .	. . . .	.40	. . . .	. . . .	. . . .	
Pears	Per barrel	. . . .	. . . .	.35	. . . .	. . . .	. . . .	
Melons	Per barrel	. . . .	. . . .	.35	. . . .	. . . .	. . . .	
Cantaloupes	Per barrel	. . . .	. . . .	.35	. . . .	. . . .	. . . .	
Grapes	Per pound	36	. . . .	.00½	. . . .	. . . .	. . . .	
Lemons, oranges	Per box	55	. . . .	.25	. . . .	.40	. . . .	
	Per case	55	. . . .	. . . .	. . . .	.60	. . . .	
Dates and figs, etc.	Per pound	55	. . . .	.00¼	. . . .	. . . .	. . . .	
Berries	Per crate, large	36	. . . .	.35	. . . .	. . . .	. . . .	
Berries	Per crate, small	. . . .	. . . .	.25	. . . .	. . . .	. . . .	
Preserves	Per pound	. . . .	. . . .	.00⅓	. . . .	. . . .	. . . .	
Mincemeat	Per pound	. . . .	. . . .	.00¼	. . . .	. . . .	. . . .	

Mechanical Refrigeration—Rates from Principal Cold Storage Houses—Continued

Substance	Conditions Kind of package or amount	Best Temperatures, Degrees	Fraction of a Month	First Month	Each Succeeding Month	For the Season	Season Ends	General Season is from May to May
Mincemeat	Per pound	....	......	.00¼	......	....	....	
Sauerkraut	Per 33 gallon barrel	32	......	......	......	1.00	Nov. 1	
	Per 42 gallon barrel	....	......	......	......	1.25	....	
Honey, jelly, etc.	Per pound	....	......	.00¼	......	....	....	
Buckwheat	Per barrel	32	......	......	......	1.25	....	
Flour	Per pound, in sacks	....	......	......	......	.00⅛	....	
Nuts	Per pound	....	......	.00¼	......	....	....	
Garden truck, vegetables	Per pound	36 to 38	......	.25	......	....	....	
Dried corn	Per flour barrel	32 to 36	......	......	......	1.25	....	
Salt meat	Per tierce	....	......	.25 to .35	......	....	....	
	Per barrel	....	......	.20 to .25	......	....	....	
Dried beef	....	....	......	.35	......	....	....	
Lard, etc.	Per pound	....	......	.00¼	......	....	....	
Preserves	Per gallon, in jugs	33	......	......	......	.05	....	
Syrups	Per gallon, in jugs	....	......	......	......	.05	....	
Apple, peach and pear butter	Per half barrel	....	......	......	......	1.00	Dec. 1	
	Per barrel	....	......	......	......	2.00	....	
Cider	Per barrel, 33 gallons	30	......	......	......	1.00	....	
	Per barrel, 42 gallons	....	......	......	......	1.25	....	
Beer	Per half barrel	33 to 41	......	.30	......	....	....	
	Per quarter barrel	33 to 41	......	.15	......	....	....	
	Per barrel	33 to 41	......	.50	......	....	....	
Fresh meat	Per pound	38	......	.00¼	......	....	....	
	Per quarter	....	......	.25	per	month	....	$25 and upward per month
Storage room	Per 1000 cubic feet	....	......	......	......	....	....	
Veal	Per pound	36	......	.25	per	month	....	
Lamb	Per pound	....	......	.15	per	month	....	
Foreign and domestic fruits and nuts, ¼c. per month or ¾c. per season; in large lots, ½c. per season. Other goods than given in table range in quality ¼c. to ⅜c. per pound gross weight per season ending November 1st.								
Game	....	32 to 36	......	......	......	....	....	15c. per season
Ducks, grouse, quail	Per dozen	32 to 36	......	......	......	....	....	
Storage in Freezing Room Below 20 Degrees								
Game	Per pound gross	....	......	......	......	....	....	½c. per month
Venison, poultry	Per pound gross	....	......	......	......	....	....	½c. per month
Quail	Per dozen	....	......	......	......	....	....	15c. per season
Fish	....	25 to 30	......	......	......	....	....	¼c. to ½c. per mo.

The above table will serve as a guide until the cost, based on running expenses, to suit your particular trade, can be established to suit demand of locality.

ICE MANUFACTURE.

APPROXIMATE COST OF OPERATING ICE FACTORIES.

Tons Ice per Day.	Engineers $1.50 to $5.00 per Day.		Night Eng'r or Oilers $1.50 per Day.		Firemen $1.50 per Day.		Tankmen and Laborers $1.00 per Day.		Pipe Fitter or Machinist $2.50 per Day.		Coal 15 Cts. per Cwt., or $3.00 per Ton.		Oil Waste, Lights and Sundries.	Daily Operating Expenses.	Ice per Ton.
1	1	$1.50		......		......	1	$1.00		......	900	$1.35	$0.50	$4.35	$4.35
2	1	1.50		......		......	1	1.00		......	1,500	2.25	.50	5.25	2.63
3	1	2.00		......		......	1	1.00		......	1,800	2 70	.50	6.20	2.10
4	1	1.75	1	$1.50		......	1	1.00		......	2,200	3.30	.75	8.30	2.08
5	1	2.00	1	1.50		......	2	2.00		......	2,500	3.75	1 00	10.25	2.05
6	1	2.00	1	1.50		......	2	2.00		......	2,700	4.05	1.00	10.55	1.76
7½	1	2.00	1	1.50	1	$1.50	2	2 00		......	3,200	4.80	1.25	13.05	1.74
10	1	2.50	1	1.50	2	3.00	2	2.00		......	3,600	5.40	1.25	15.65	1.57
12½	1	2.50	1	1.50	2	3.00	2	2.00		......	4,500	6.75	1.25	17.00	1.37
15	1	2.50	1	1.50	2	3.00	3	3.00		......	5,000	7.50	1.50	19.00	1.27
18	1	2.75	1	1.50	2	3.00	3	3.00		......	5,500	8.25	1.80	20.30	1.15
20	2	4.50	1	1.50	2	3.00	3	3.00		......	6,000	9.00	2.00	23.00	1.15
25	2	5 00	1	1.50	2	3.00	4	4.00		......	7,500	11.25	2.50	27.25	1.09
30	2	5.00	2	3.00	2	3.00	4	4.00		......	9,000	13.50	3.00	31.50	1.05
35	2	6.00	2	3.00	2	3.00	5	5.00		......	10,500	15.75	3.50	36.25	1.03
40	2	6.00	2	3.00	2	3.00	5	5.00		......	12,000	18.00	4.00	39.00	1.00
45	2	6.00	2	3.00	2	3.00	6	6.00		......	13,500	20.25	4.50	42.75	1.00
50	2	6.50	2	3.00	3	4.50	6	6.00	1	$2.50	15,000	22.50	5.00	50.00	1.00
55	2	6.50	2	3.00	3	4.50	7	7.00	1	2.50	16,500	24.75	5.50	53.75	1.00
60	2	7.00	2	3.00	4	6.00	7	7.00	1	2.50	18,000	27.00	6.00	58.50	1.00
65	2	7.50	2	3.00	5	7.50	8	8.00	1	2.50	19,500	29.25	6.50	64.25	1.00
70	2	7.50	2	3.00	5	7.50	8	8.00	1	2.50	21,000	31.50	7.00	67 00	.99
75	2	8.00	2	3.00	5	7.50	10	10.00	2	5 00	22,500	33.75	7.50	74.75	.99
80	2	9.00	2	3.00	5	7.50	10	10.00	2	5.00	24,000	36.00	8.00	78.50	.98
90	3	10.00	2	3.00	6	9.00	11	11.00	2	5.00	27,000	40.50	9.00	87.50	.96
100	3	10.00	2	3.00	7	10.50	12	12.00	2	5.00	30,000	45.00	10.00	95.50	.95

The rate of wages and cost of fuel in the locality where machinery is to be used will change above figures slightly.

Cold Storage Temperatures

Articles	Degr. Fahr.	Articles	Degr. Fahr.	Articles	Degr. Fahr.
Fruit		**Fish**		**Vegetables**	
Apples	32-36	Fresh fish	20	Asparagus	34-35
Bananas	34	Dried fish	36	Cabbage	34-35
Berries, fresh	36	Oysters in shell	30-35	Carrots	34-35
Cranberries	33-36	Oysters in tubs	25	Celery	34-35
Cantaloupes	40	**Canned Goods**		Dried beans	32-40
Dates, figs, etc.	50-55	Sardines	35-40	Dried corn	35
Fruits, dried	35-40	Fruits	35-40	Dried peas	35-40
Grapes	34-36	Meats	35-40	Onions	36
Lemons	33-36	**Butter, Eggs, etc.**		Parsnips	34-35
Oranges	34-36	Butter	18-20	Potatoes	36-40
Peaches	34-36	Butterine	18-20	Sauerkraut	35
Pears, watermelons	34-36	Cheese	34		
		Eggs	31	**Miscellaneous**	
Meats		**Liquids**		Cigars, tobacco	35
Brined	38	Beer, ale, porter, etc.	33	Furs, woolens, etc.	35
Beef, fresh	33	Cider	30	Honey	45
Beef, dried	36-40	Ginger ale	36	Hops	40
Calves	32-33	Wines	40-45	Maple syrup, sugar	40-45
Hams, ribs, shoulders (not brined)	20	**Flour and Meal**		Oils	35
Hogs	29-32	Buckwheat flour	36-40	Poultry, dressed, iced	28-30
Lard	38	Corn meal	36-40	Poultry, dry picked	26-28
Livers	20-30	Oat meal	36-40	Poultry, scalded	20
Sheep, lambs	32	Wheat flour	36-40	Game, to freeze	15-18
Ox-tails	30			Game, after frozen	25-28
Sausage casings	20			Poultry, to freeze	15-18
Tenderloin, butts, etc.	33			Poultry, after frozen	25-28
				Nuts in shells	35-40
				Chestnuts	33

Specific and Latent Heat of Various Food Products

Substance	Composition		Specific Heat Above Freezing in Heat Units	Specific Heat Below Freezing in Heat Units	Latent Heat of Freezing in Heat Units
	Water	Solids			
Lean beef	72.00	28.00	0.77	0.41	102
Fat beef	51.00	49.00	.60	.34	73
Veal	63.00	37.00	.70	.39	90
Fat Pork	39.00	61.00	.51	.30	55
Eggs	70.00	30.00	.76	.40	100
Potatoes	74.00	26.00	.80	.42	105
Cabbage	91.00	9.00	.93	.48	129
Carrots	83.00	17.00	.87	.45	118
Milk	87.50	12.50	.90	.47	124
Oysters	80.38	19.62	.84	.44	114
Whitefish	78.00	22.00	.82	.43	111
Eels	62.07	37.93	.69	.38	88
Lobster	76.62	23.38	.81	.42	108
Pigeon	72.40	27.60	.78	.41	102
Chicken	73.70	26.30	.80	.42	105

The figures in the last column showing the latent heat of freezing, have been obtained by multiplying the latent heat of freezing water, which is 142 heat units, by the per cent. of water contained in the different materials considered, for as the solid constituents remain in their original condition, only the liquid or watery portion of these materials are concerned in the solidification or freezing of them.

WEIGHT, SPECIFIC GRAVITY, SPECIFIC HEAT, MELTING POINT AND LATENT HEAT OF SOLID BODIES.

	Weight of One Cubic Foot, Lbs.	Specific Gravity, Water=1.	Specific Heat, Water at 32°=1.	Melting or Freezing Point, F.	Latent Heat of Fusion in 1 Lb.
Aluminum	162	2.6	-----	1100-1300	-----
Antimony	418	6.7	0.0507	850	-----
Asbestos, natural	143.4	2.300	-----	-----	-----
Asphaltum	87.3	1.4	-----	-----	-----
Ash	34.3	.55	.200	-----	-----
Alcohol	-----	-----	-----	—148	-----
Ammonia, anhydrous	39.1	.626	-----	—104	-----
Acetic Acid	-----	-----	-----	113	-----
Bismuth	614	9.82	.03084	507	22.7
Brass	530	8.5	.09391	1869	-----
Bronze	530	8.5	-----	1692	-----
Brick, common	115	1.8	-----	-----	-----
" fire	150	2.4	-----	-----	-----
Brick-work in mortar	100	1.6	.200	-----	-----
" in cement	110	1.8	.200	-----	-----
Bone	112-124	1.8-2	-----	-----	-----
Butter	58.7	.94	-----	-----	-----
Bromine	187.48	3.00	.0840	9.5	-----
Copper	542	8.7	.09515	1996	-----
Cement, Portland	78-94	1.25-1.51	-----	-----	-----
Chalk, air dried	150-159	2.46-2.55	.21485	-----	-----
Clay, potter	120	1.9	-----	-----	-----
Coal, anthracite	100	1.602	.201	-----	-----
" bituminous	77-90	1.24-1.44	.20	-----	-----
Coke	47	0.7	.2031	-----	-----
Concrete, Portland	120	1.9	-----	-----	-----
Concrete lime	118	1.8	-----	-----	-----
Cotton	121.6	1.95	-----	-----	-----
Cork	15.6	.25	-----	-----	-----
Earth, vegetable	90	1.4	-----	-----	-----
" loamy	100	1.6	-----	-----	-----
" semi-fluid	110	1.7	-----	-----	-----
Emery	250	4.0	-----	-----	-----
Gold	720.3	19.258	.03244	2016	-----
Gun Metal	549	8.78	-----	-----	-----
Glass, white flint	188	3.0	.19	2200	-----
" plate	168.4	2.70	-----	-----	-----
" crown	156	2.50	-----	-----	-----
Granite	164	2.63	-----	-----	-----
Gravel	124	1.99	-----	-----	-----
Gutta Percha	60.5	.97	-----	-----	-----
Grain, wheat heaped	46.7	.75	-----	-----	-----
" barley "	36.6	.59	-----	-----	-----
" oats "	31.2	.50	-----	-----	-----
Flax	111.6	1.79	-----	-----	-----
Fat, pork	58.7	.94	-----	-----	-----
" mutton	57.4	.92	-----	-----	-----
" beef	57.68	.925	-----	-----	-----
Ice at 32° F.	57.5	.92	.504	32	142.6
India Rubber	58	.93	-----	-----	-----
Iron, wrought	480	7.698	.11379	2800	-----
" cast	450	7.217	.12983	2200	-----
Ivory	114	1.83	-----	-----	-----

WEIGHT, SPECIFIC GRAVITY, ETC., OF SOLID BODIES.—(Continued.)

	Weight of One Cubic Foot Lbs.	Specific Gravity, Water=1.	Spec. Heat, Water at 32°=1.	Melting or Freezing Point, Fahr.	Lat'nt Heat of Fusion in 1 Pound.
Limestone	168	2.70	.215	......	......
Lead	712	11.4	.0314	617	9.68
Lime, ordinary quick	53	.85	.2169	......	......
Lard	59.3	.95	......	......	......
Mercury	849	13.6	.0319	—39	5
Marble, average	170	2.7	.215	......	......
Masonry, granite	165	2.64	.20	......	......
Mortar, old	90	1.4	......	......	......
Mortar, new	110	1.7	......	......	......
Mud, dry	80–110	1.278–1.7	......	......	......
Mud, fluid	104–120	1.66–1.9	......	......	......
Magnesium	109	1.75	......	......	......
Maple, dry	49	.78	......	......	......
Masonry, dry rubble	120	1.90	......	......	......
Mica	183	2.97	......	......	......
Nickel	561	9.	.10863	2800	......
Oak, live, dry	59	.95	......	......	......
" white	50	.80	......	......	......
Pewter	466	7.471	......	......	......
Platinum	1342	21.5	.0325	4500	......
Phosphorus	110.4	1.77	.1788	110	9
Peat, condensed	62.5–81.1	1.0–1.3	......	......	......
Pitch	72	1.15	......	......	......
Plaster of Paris	80	1.2	.1966	......	......
Porcelain, Chinese	148.4	2.385	......	......	......
Petroleum	55	.88	......	......	......
Plumbago	140	2.27	......	......	......
Quartz	165	2.65	......	......	......
Silver	654	10.47	.05701	1750	37.9
Steel	490	7.84	.1165	2500	......
Sulphurous chloride	......	......	......	—148	......
Sulphur	124.7	2.07	.1764	230	17
Snow, fresh fallen	5–12	0.08–0.19	......	......	......
Snow, compact	15–50	0.24–0.8	......	......	......
Sand, fine and dry	100.	1.5	......	......	......
Sand, fine and damp	124.71	2.00	......	......	......
Sand, coarse	93.53	1.5	......	......	......
Salt, rock	131–140.7	2.1–2.257	......	......	......
Salt, common	119.7	1.72	......	......	......
Sandstone	145	2.3	......	......	......
Slate	162–177.7	2.6–2.85	......	......	......
Tin	462	7.409	.0562	442	25.6
Turpentine	......	5.013	......	14	......
Tallow	58.6	.94	......	92	......
Tiles, average	115	1.8	......	......	......
Tar	62.4	1.00	......	......	......
Water, distilled 60° F.	62.3	1.0	......	......	......
" Sea	64.3	1.03	......	......	......
White lead	197	3.16	......	......	......
Wool	100.4	1.61	......	......	......
Wax, bees	60.5	0.97	......	142	175
Wood, oak	54.2	.87	.57	......	......
Wood, yellow pine	28.7	0.46	.65	......	......
Zinc	428	6.86	.09555	773	50.6

WEIGHT OF VARIOUS SUBSTANCES PER CUBIC FOOT.

	Pounds		Pounds
Mercury	848.7	Olive oil	57.1
Brine	77.4	Turpentine	54.3
Milk	64.3	Petroleum	54.9
Sea water	64.05	Naphtha	53.1
Pure water	62.425	Alcohol	57.4
Linseed oil	58.7	Benzine	53.1
Whale oil	57.4	Wine	62
Sugar	40	Ash	34.3
Soap	40	Ice	57.5
Salt	44	Earth	93
Dry fruits	45	Soft coal	80
Lime	44	Hard coal	85
Tobacco	80	Stone	178
Oil, average	56	Masonry	143
Eggs	25	Sand	119
Fruit	22	Cast iron	466
Butter	58.7	Wrought iron	487
Fat	58	Brass	505
Oak, white	26	Charcoal	25.3
Pine, yellow	20.6	Lead	567
Vinegar	67.5	Beer	64.62
Beef fat	57.68	Snow	5.2
Hog fat	58.50	Ammonia (28%)	55.68

TIME OF FREEZING ICE WITH 14° BRINE.

Weight of Blocks.	Size of Can.	Time of Freezing.
50 lbs.	6" × 12" × 26"	15 hrs.
100 "	8" × 16" × 32"	30 "
150 "	8" × 16" × 42"	30 "
200 "	11" × 22" × 32"	50 "
300 "	11" × 22" × 44"	50 "
400 "	11" × 22" × 57"	50 "

DECIMAL EQUIVALENTS OF A FOOT FOR EACH 1-16 OF AN INCH

Inch	0"	1"	2"	3"	4"	5"	6"	7"	8"	9"	10"	11"
0	.0	.0833	.1677	.2500	.3333	4167	.5000	.5833	.6667	.7500	.8333	.9167
1-16	.0052	.0885	.1719	.2552	.3385	.4219	.5052	.5885	.6719	.7552	.8385	.9219
1-8	.0104	.0937	.1771	2604	.3437	.4271	.5104	.5937	.6771	.7604	.8437	.9271
3-16	.0156	.0990	.1823	.2656	.3490	.4323	.5156	.5990	.6823	.7656	.8490	9323
1-4	.0208	.1042	.1875	.2708	.3542	.4375	.5208	.6042	.6875	.7708	.8542	.9375
5-16	0260	1094	.1927	.2760	.3594	.4427	.5260	.6094	.6927	.7760	.8594	.9427
3-8	0312	.1146	.1979	2812	.3646	.4479	.5312	.6146	.6979	7812	.8646	.9479
7-16	.0365	.1198	.2031	.2865	.3698	.4531	.5365	.6198	.7031	.7865	.8698	9531
1-2	.0417	.1250	2083	.2917	.3750	.4583	.5417	.6250	.7083	.7917	.8750	.9583
9-16	.0469	.1302	.2135	.2969	.3802	.4635	.5469	.6302	.7135	.7969	8802	.9635
5-8	.0521	.1354	.2188	3021	.3854	.4688	.5521	.6354	.7188	.8021	.8854	9688
11-16	.0573	.1406	.2240	.3073	.3906	.4740	.5573	.6406	.7240	.8073	.8906	.9740
3-4	.0625	.1458	.2292	3125	.3958	.4792	.5625	.6458	.7292	8125	.8958	.9792
13-16	.0677	.1510	.2344	.3177	4010	.4844	.5677	6510	.7344	.8177	.9010	.9844
7-8	.0729	.1562	.2396	.3229	4062	4896	5729	.6562	7396	.8229	.9062	.9896
15-16	.0781	.1615	2448	.3281	4115	.4948	.5781	6615	7448	.8281	9115	.9948

DECIMAL EQUIVALENTS FOR EACH 1-64 OF AN INCH

1-64	.015625	17-64	.265625	33-64	.515625	49-64	.765625
1-32	.03125	9-32	.28125	17-32	.53125	25-32	.78125
3-64	.046875	19-64	.296875	35-64	.546875	51-64	.796875
1-16	.0625	**5-16**	.3125	**9-16**	.5625	**13-16**	.8125
5-64	.078125	21-64	.328125	37-64	.578125	53-64	.828125
3-32	.09375	11-32	.34375	19-32	.59375	27-32	.84375
7-64	.109375	23-64	.359375	39-64	.609375	55-64	.859375
1-8	.125	**3-8**	.375	**5-8**	.625	**7-8**	.875
9-64	.140625	25-64	.390625	41-64	.640625	57-64	.890625
5-32	.15625	13-32	.40625	21-32	.65625	29-32	.90625
11-64	.171875	27-64	.421875	43-64	.671875	59-64	.921875
3-16	.1875	**7-16**	.4375	**11-16**	.6875	**15-16**	.9375
13-64	.203125	29-64	.453125	45-64	.703125	61-64	.953125
7-32	.21875	15-32	.46875	23-32	.71875	31-32	.96875
15-64	.234375	31-64	.484375	47-64	.734375	63-64	.984375
1-4	.25	**1-2**	.5	**3-4**	.75	**1**	....

COMPARISON OF U. S. AND METRIC WEIGHTS AND MEASURES.

United States Measures	=	*Metric Measures.*
1 Grain	=	.0648 Grammes.
1 Ounce	=	28.3502 "
1 Pound, avoirdupois	=	.4536 Kilogrammes.
1 Pound, avoirdupois	=	453.6028 Grammes
1 Ton, 2,240 lbs	=	1016.0578 Kilogrammes.
1 Inch	=	25.4 Millimeters.
1 Inch	=	2.54 Centimeters.
1 Foot	=	.3048 Meters.
1 Yard	=	.9144 "
1 Mile	=	1.6093 Kilometers.
1 Square Inch	=	645.16 Square Millimeters.
1 " Inch	=	6.4516 " Centimeters.
1 " Foot	=	.0929 " Meters.
1 " Yard	=	.8361 " "
1 Acre	=	40.47 Are (100 sq. Meters)
1 Acre	=	.4047 Hectare (10,000 "
1 Square Mile	=	2.59 Square Kilometers.
1 Cubic Inch	=	16.39 Cubic Centimeters.
1 " Foot	=	.02832 " Meters.
1 " Yard	=	.7646 " Meters.
1 Quart, dry measure	=	1.101 Liters.
1 Quart, liquid	=	.9465 "
1 Gallon	=	3.785 "
1 Barrel (31½ Gals.)	=	119.23 "
1 Barrel "	=	1.1922 Hectoliters.
1 Foot Pound	=	.1383 Kilogrammeter.
1 Pound per foot	=	1.488 Kgr'meter per meter.
1 Pound per square inch	=	.0703 Kilogrs. p. sq. Cm.
1,000 lbs. per square inch	=	.703 Kilogrs. per sq. Mm.
1 Pound per square foot	=	4.882 Kilogrs. p. sq. meter.
1 Pound " cubic "	=	16.02 Kgrs. per cubic meter.
1 Degree Fahrenheit	=	.5556 Degree Centigrade.

Metric Measures	=	*United States Measures.*
1 Gramme	=	15.4323 Grains.
1 Gramme	=	.0353 Ounces.
1 Kilogramme	=	2.2047 Pounds, avoirdupois
1 Kilogramme	=	35.27 Ounces.
1 Tonne	=	1.1024 Tons, 2,240 lbs.
1 Millimeter	=	.0394 Inches.
1 Centimeter	=	.3937 Inches.
1 Meter	=	39.3704 Inches (3 ft. 3⅜ in.)
1 Meter	=	1.0936 Yards (1 1-10 yds.)
1 Kilometer	=	.6214 Miles.
1 Square Millimeter	=	.0015 Square Inches.
1 " Centimeter	=	.155 " "
1 " Meter	=	10.763 " Feet.
1 " Meter	=	1.196 " Yards.
1 Are (100 sq. meters)	=	.0247 Acres.
1 Hectare (10,000 sq. meters)	=	2.4711 "
1 Square Kilometer	=	.3861 Square Miles.
1 Cubic Centimeter	=	.0610 Cubic Inches.
1 " Meter or Stere	=	35.3156 " Feet.
1 " "	=	1.3078 " Yards.
1 Liter (1 Cub. Decimeter)	=	61.023 " Inches.
1 Liter	=	.908 Quarts, dry measure
1 Liter	=	1.0566 " liquid meas.
1 Hectoliter	=	26.418 Gallons.
1 Hectoliter	=	.838 Barrel (31½ gals.)
1 Kilogrammeter	=	7.2331 Foot Pounds.
1 " " per meter	=	.6720 Pounds per foot.
1 Kilogramme per sq. centimeter	=	14.22 Pounds per sq. inch.
1 Kilogrammeter per sq. millimeter	=	1422.34 " " "
1 Kilogramme per sq. meter	=	.2048 " " foot.
1 " " " cubic meter	=	.0624 " per cub. ft.
1 Degree Centigrade	=	1.8 Degrees Fahrenheit.

Table for Converting Head of Water into Equivalent Pressure.

Feet Head.	Pounds per Square Inch.	Feet Head.	Pounds per Square Inch.
1	.43	100	43.30
2	.87	110	47.63
3	1.30	120	51.96
4	1.73	130	56.29
5	2.17	140	60.62
6	2.60	150	64.95
7	3.03	160	69.28
8	3.46	170	73.61
9	3.90	180	77.94
10	4.33	190	82.27
15	6.50	200	86.60
20	8.66	225	97.42
25	10.83	250	108.25
30	12.99	275	119.08
35	15.16	300	129.91
40	17.32	325	140.73
45	19.49	350	151.56
50	21.65	375	162.38
55	23.82	400	173.21
60	25.98	500	216.51
65	28.15	600	259.81
70	30.31	700	303.11
75	32.48	800	346.42
80	34.64	900	389.72
85	36.81	1000	433.02
90	38.97	1100	476.32
95	41.14	1200	519.62

Table for Converting Pressure of Water into Equivalent Head.

Pounds per Square Inch.	Feet Head.	Pounds per Square Inch.	Feet Head.
1	2.31	100	230.95
2	4.62	110	254.04
3	6.93	120	277.14
4	9.24	130	300.23
5	11.55	140	323.33
6	13.86	150	346.42
7	16.17	160	369.52
8	18.48	170	392.61
9	20.78	180	415.71
10	23.09	190	438.80
15	34.64	200	461.89
20	46.19	225	519.63
25	57.74	250	577.36
30	69.28	275	635.10
35	80.83	300	692.85
40	92.38	325	750.59
45	103.93	350	808.32
50	115.47	375	866.06
55	127.02	400	923.80
60	138.57	425	981.54
65	150.12	450	1039.27
70	161.66	475	1097.01
75	173.21	500	1154.75
80	184.76	525	1212.49
85	196.31	550	1270.22
90	207.85	575	1327.96
95	219.40	600	1385.70

1 lb. water per sq. inch is equivalent to a head of water of 2.309 feet.
14.7 lbs., or 1 atmosphere, " " " " " " 33.9 "
1 foot of water is equivalent to a pressure of 0.433 lbs. per sq. inch, or to 62.35 lbs. per sq. foot.

TABLE OF THEORETICAL HORSE POWER REQUIRED TO RAISE WATER TO DIFFERENT HEIGHTS.

Gals. per min.	5′	10′	15′	20′	25′	30′	35′	40′	45′	50′	60′	75′	90′	100′	125′	150′	175′	200′	250′	300′	350′	400′	Gals. per min.
5	.006	.012	.019	.025	.031	.037	.044	.05	.06	.06	.07	.09	.11	.12	.16	.19	.22	.25	.31	.37	.44	.50	5
10	.012	.025	.037	.050	.062	.075	.087	.10	.11	.12	.15	.19	.22	.25	.31	.37	.44	.50	.62	.75	.87	1.00	10
15	.019	.037	.056	.075	.094	.112	.131	.15	.17	.19	.22	.28	.34	.37	.47	.56	.66	.75	.94	1.12	1.31	1.50	15
20	.025	.050	.075	.100	.125	.150	.175	.20	.22	.25	.30	.37	.45	.50	.62	.75	.87	1.00	1.25	1.50	1.75	2.00	20
25	.031	.062	.093	.125	.156	.187	.219	.25	.28	.31	.37	.47	.56	.62	.78	.94	1.09	1.25	1.56	1.87	2.19	2.50	25
30	.037	.075	.112	.150	.187	.225	.262	.30	.34	.37	.45	.56	.67	.75	.94	1.12	1.31	1.50	1.87	2.25	2.62	3.00	30
35	.043	.087	.131	.175	.219	.262	.306	.35	.39	.44	.52	.66	.79	.87	1.08	1.31	1.53	1.75	2.19	2.62	3.06	3.50	35
40	.050	.100	.150	.200	.250	.300	.350	.40	.45	.50	.60	.75	.90	1.00	1.25	1.50	1.75	2.00	2.50	3.00	3.50	4.00	40
45	.056	.112	.168	.225	.281	.337	.394	.45	.51	.56	.67	.84	1.01	1.12	1.41	1.69	1.97	2.25	2.81	3.37	3.94	4.50	45
50	.062	.125	.187	.250	.312	.375	.437	.50	.56	.62	.75	.94	1.12	1.25	1.56	1.87	2.19	2.50	3.12	3.75	4.37	5.00	50
60	.075	.150	.225	.300	.375	.450	.525	.60	.67	.75	.90	1.12	1.35	1.50	1.87	2.25	2.62	3.00	3.75	4.50	5.25	6.00	60
75	.093	.187	.281	.375	.469	.562	.656	.75	.84	.94	1.12	1.40	1.69	1.87	2.34	2.81	3.28	3.75	4.69	5.62	6.56	7.50	75
90	.112	.225	.337	.450	.562	.675	.787	.90	1.01	1.12	1.35	1.68	2.02	2.25	2.81	3.37	3.94	4.50	5.62	6.75	7.87	9.00	90
100	.125	.250	.375	.500	.625	.750	.875	1.00	1.12	1.25	1.50	1.87	2.25	2.50	3.12	3.75	4.37	5.00	6.25	7.50	8.75	10.00	100
125	.156	.312	.469	.625	.781	.937	1.094	1.25	1.41	1.56	1.87	2.34	2.81	3.12	3.91	4.69	5.47	6.25	7.81	9.37	10.94	12.50	125
150	.187	.375	.562	.750	.937	1.125	1.312	1.50	1.69	1.87	2.25	2.81	3.37	3.75	4.69	5.62	6.56	7.50	9.37	11.25	13.12	15.00	150
175	.219	.437	.656	.875	1.093	1.312	1.531	1.75	1.97	2.19	2.62	3.28	3.94	4.37	5.47	6.56	7.66	8.75	10.94	13.12	15.31	17.50	175
200	.250	.500	.750	1.000	1.250	1.500	1.750	2.00	2.25	2.50	3.00	3.75	4.50	5.00	6.25	7.50	8.75	10.00	12.50	15.00	17.50	20.00	200
250	.312	.625	.937	1.250	1.562	1.875	2.187	2.50	2.81	3.12	3.75	4.69	5.62	6.25	7.81	9.37	10.94	12.50	15.72	18.75	21.87	25.00	250
300	.375	.750	1.125	1.500	1.875	2.250	2.625	3.00	3.37	3.75	4.50	5.62	6.75	7.50	9.37	11.25	13.12	15.00	18.75	22.50	26.25	30.00	300
350	.437	.875	1.312	1.750	2.187	2.625	3.062	3.50	3.94	4.37	5.25	6.56	7.87	8.75	10.94	13.12	15.31	17.50	21.87	26.25	30.62	35.00	350
400	.500	1.000	1.500	2.000	2.500	3.000	3.500	4.00	4.50	5.00	6.00	7.50	9.00	10.00	12.50	15.00	17.50	20.00	25.00	30.00	35.00	40.00	400
500	.625	1.250	1.875	2.500	3.125	3.750	4.375	5.00	5.62	6.25	7.50	9.37	11.25	12.50	15.62	18.75	21.87	25.00	31.25	37.50	43.75	50.00	500

The **Theoretical Horse Power** required to elevate water is found by multiplying the *gallons* pumped per *minute* by the total lift (including pipe friction) *in feet* and dividing by 4000.

The **Actual Horse Power** for 100 foot lift is 1.7 times the Theoretical Horse Power, for a 200 foot lift 1.45 times, and for a 300 foot lift 1.25 times.

Areas of Circles

Advancing by eighths

Diam.	0	1/8	1/4	3/8	1/2	5/8	3/4	7/8
	0	.0122	.0490	.1104	.1963	.3068	.4417	.6013
1	.7854	.9940	1.227	1.484	1.767	2.073	2.405	2.761
2	3.1416	3.546	3.976	4.430	4.908	5.411	5.939	6.491
3	7.068	7.669	8.295	8.946	9.621	10.32	11.04	11.79
4	12.56	13.36	14.18	15.03	15.90	16.80	17.72	18.66
5	19.63	20.62	21.64	22.69	23.75	24.85	25.96	27.10
6	28.27	29.46	30.67	31.91	33.18	34.47	35.78	37.12
7	38.48	39.87	41.28	42.71	44.17	45.66	47.17	48.70
8	50.29	51.84	53.45	55.08	56.74	58.42	60.13	61.86
9	63.61	65.39	67.20	69.02	70.88	72.75	74.69	76.58
10	78.54	80.51	82.51	84.54	86.59	88.66	90.76	92.88
11	95.03	97.20	99.40	101.6	103.8	106.1	108.4	110.7
12	113.0	115.4	117.8	120.2	122.7	125.1	127.6	130.1
13	132.7	135.2	137.8	140.5	143.1	145.8	148.4	151.2
14	153.9	156.6	159.4	162.2	165.1	167.9	170.8	173.7
15	176.7	179.6	182.6	185.6	188.6	191.7	194.8	197.9
16	201.0	204.2	207.3	210.5	213.8	217.0	220.3	223.6
17	226.9	230.3	233.7	237.1	240.5	243.9	247.4	250.9
18	254.4	258.0	261.5	265.1	268.8	272.4	276.1	279.8
19	283.5	287.2	291.0	294.8	298.6	302.4	306.3	310.2
20	314.1	318.1	322.0	326.0	330.0	334.1	338.1	342.2
21	346.3	350.4	354.6	358.8	363.0	367.2	371.5	375.8
22	380.1	384.4	388.8	393.2	397.6	402.0	406.4	410.9
23	415.4	420.0	424.5	429.1	433.7	438.3	433.0	447.6
24	452.3	457.1	461.8	466.6	471.4	476.2	481.1	485.9
25	490.8	495.7	500.7	505.7	510.7	515.7	520.7	525.8
26	530.9	536.0	541.1	546.3	551.5	556.7	562.0	567.2
27	572.5	577.8	583.2	588.5	593.9	599.3	604.8	610.2
28	615.7	621.2	626.7	632.3	637.9	643.5	649.1	654.8
29	660.5	666.2	671.9	677.7	683.4	689.2	695.1	700.9
30	706.8	712.7	718.6	724.6	730.6	736.6	742.6	748.6
31	754.8	760.9	767.9	773.1	779.3	785.5	791.7	798.0
32	804.3	810.6	816.9	823.2	829.6	836.0	842.4	848.8
33	855.3	861.8	868.3	874.9	881.4	888.0	894.6	901.3
34	907.9	914.7	921.3	928.1	934.8	941.6	948.4	955.3
35	962.1	969.0	975.9	982.8	989.8	996.8	1003.8	1010.8
36	1017.9	1025.0	1032.1	1039.2	1046.3	1053.5	1060.7	1068.0
37	1075.2	1082.5	1089.8	1097.1	1104.5	1111.8	1119.2	1126.9
38	1134.1	1141.6	1149.1	1156.6	1164.2	1171.7	1179.3	1186.7
39	1194.6	1202.3	1210.0	1217.7	1225.4	1233.2	1241.0	1248.8
40	1256.6	1264.5	1272.4	1280.3	1288.2	1296.2	1304.2	1312.2
41	1320.3	1328.3	1336.4	1344.5	1352.7	1360.8	1369.0	1377.2
42	1385.4	1393.7	1402.0	1410.3	1418.6	1427.0	1435.4	1443.8
43	1452.2	1460.7	1469.1	1477.6	1486.2	1494.7	1503.3	1511.9
44	1520.5	1529.2	1537.9	1546.6	1555.3	1564.0	1572.8	1581.6
45	1590.4	1599.3	1608.2	1617.0	1626.0	1634.9	1643.9	1652.9

The area of a circle is equal to the square of the diameter multiplied by 0.7854
The circumference of a circle is equal to the diameter multiplied by 3.1416.

CAPACITIES OF TANKS IN BARRELS OF 31½ GALLONS.

Depth in Feet.	DIAMETER IN FEET.														
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
5	23.3	33.6	45.7	59.7	75.5	93.2	112.8	134.3	157.6	182.8	209.8	238.7	269.5	302.1	336.6	373.0
6	28.0	40.3	54.8	71.7	90.6	111.0	135.4	161.1	189.1	219.3	251.8	286.5	323.4	362.6	404.0	447.6
7	32.7	47.0	64.0	83.6	105.7	130.6	158.0	188 0	220.6	255.9	293.7	334.2	377.3	423.0	471.3	522.2
8	37.3	53.7	73.1	95.5	120 9	149.1	180.5	214.8	252.1	292.4	335.7	382.0	431.2	483.4	538.6	596.8
9	42.0	60.4	82.2	107.4	136.0	167.9	203.1	241.7	283.7	329.0	377.7	429.7	485.1	543.8	605.9	671.4
10	46.7	67.1	91.4	119.4	151.1	186 5	225.7	268.4	315.2	365.5	419.6	477.4	539.0	604.3	673.3	746.0
11	51.3	73.9	100.5	131.3	166.2	205.1	248 2	295.4	346.7	402.1	461.6	525.2	592.9	667.7	740.6	820.6
12	56.0	80.6	109 7	143.2	181.3	223 8	270.8	322.3	378.2	438.6	503.5	572.0	646.8	725.1	807.9	895.2
13	60.7	87.3	118.8	155.2	196.4	242.4	293.4	349.1	409.7	475.2	545.5	620 7	700.7	785.5	875.2	969.8
14	65.3	94.0	127.9	167.1	211.5	261.1	315.9	376.0	441.3	511.0	587.5	668.2	754.6	846.0	942.6	1044.4
15	70.0	100.7	137.1	179.0	226.6	279 8	338.5	402.8	472.8	548.3	629.4	716.2	808.5	906.4	1009.9	1119.0
16	74.7	107.4	146.2	191 0	241.7	298.4	361.1	429.7	504.3	584.9	671.4	773.9	862.4	966.8	1077.2	1193.6
17	79.3	114.1	155.4	202.9	556.8	317.0	383.6	456.6	535.8	621.4	713.4	811.6	916.3	1027.2	1144.6	1268.2
18	84.0	120.9	164.5	214.8	272.0	335.7	406.2	483.4	567.3	658.0	755.3	859.4	970.2	1087.7	1211.9	1342.8
19	88.7	127.6	173.6	226.8	287.0	354.3	428.8	510.3	598.0	694.5	797.3	907.1	1024.1	1148.1	1279.2	1417.4
20	93.3	134.3	182.8	238.7	302.1	373.0	451.3	537.1	634.4	731.1	839.3	954.9	1078.0	1208.5	1346.5	1492.0

TO FIND CAPACITY OF ANY SIZE TANK.

Diameter in feet × diameter in feet × depth in feet × 5.878 — Gallons.
Diameter in feet × diameter in feet × depth in feet × .1865 — Barrels of 31½ Gals.
Cylindrical Inches × .0034 — Gallons.

TABLE GIVING COMPARATIVE VALUE OF DIFFERENT INSULATING MATERIALS.

NOTE.—This table gives the conducting power for each *square foot* of surface, and the comparative value is expressed in the number of *units of heat lost per hour* by transmission through them. They are arranged in the order of their merit.

	Units Lost		Units Lost
Copper	515.	Brick dust	1.33
Iron	233.	Coke dust	1.29
Zinc	225.	Cork	1.15
Marble	28.	Chalk powder	0.87
Stone	17.	Charcoal powder	0.64
Glass	7.	Straw chopped	0.56
Brick work	5.	Coal dust	0.54
Plaster	4.	Hemp canvas	0.41
Double windows	3.6	Muslin	0.40
Oak wood	1.7	Writing paper	0.34
Walnut wood	0.8	Cotton	0.32
Pine wood	0 75	Air confined	0.3
Sawdust	0.55	Gray blotting paper	0.27
India Rubber	1.37		

BAROMETRIC PRESSURE AT DIFFERENT ALTITUDES, WITH EQUIVALENT HEAD OF WATER AND THE VERTICAL SUCTION LIFT OF PUMPS.

Altitude.	Barometric Pressure, Pounds Per Sq. In.	Equivalent Head of Water, Feet.	Practical Suction Lift, Feet.
Sea level	14.70	33.95	25
¼ mile (1,320 ft.) above sea	14.02	32.38	24
½ mile (2,640 ft.) above sea	13.33	30.79	23
¾ mile (3,960 ft.) above sea	12.66	29.24	21
1 mile (5,280 ft.) above sea	12.02	27.76	20
1¼ miles (6,600 ft.) above sea	11.42	26.38	19
1½ miles (7,920 ft.) above sea	10.88	25.13	18
2 miles (10,560 ft.) above sea	9.88	22.82	17

Number of B. T. U's required to raise the temperature of, and saturate; 1000 cu. ft. of air of 80% relative humidity, and barometric pressure of 30 in.

Initial Conditions				FINAL TEMPERATURES									
Dew Point	Vapor Tension	Air Temp.		85°	90°	95°	100°	105°	110°	115°	120°	125°	130°
69°	0.693	75°	1	1007.4	1417.1	1907.9	2420.6	3006.9	3654.4	4374.4	5244.6	6160.6	7152.9
			2	828.4	1148.7	1550 0	1973.2	2470 0	3028.0	3658.6	4439.3	5265.8	6168.7
			3	179.0	268.4	357.9	447.4	536.9	626.4	715.8	805.3	894.8	984.2
			4	0.79	1.09	1.48	1.89	2.38	2.92*	3.54	4.31	5.13	6 03
73°	0.818	80°	1	708.5	1125.4	1597.9	2119.0	2679.6	3332.2	4052.2	4917.2	5828.5	6810.4
			2	619.8	948 0	1331 8	1764.2	2236 0	2799.9	3431.2	4207.5	5029.9	5923.2
			3	88.7	177 4	266.1	354.8	443.6	532.3	621.0	709.7	798.6	887.2
			4	0.59	0.90	1.27	1.69	2.15	2.70	3.32	4.09	4.90	5.79
78°	0.961	85°	1		792.1	1262.7	1771.4	2349.4	2985.7	3696.5	4571.0	5456.4	6438.7
			2		704.2	1086.8	1507.5	1997.5	2545.8	3168.7	3955.2	4750.4	5646.9
			3		87.9	175.9	263.9	351.9	439.9	527.8	615.8	706.0	791.8
			4		0.67	1 04	1.44	1.92	2.46	3.07	3.84	4.63	5.52
83°	1.126	90°	1			908.0	1412.6	1985.9	2618 6	3319.5	4179.8	5065.4	6037.7
			2			820 8	1238.2	1724.3	2269.8	2883.4	3656.5	4454.9	5340.1
			3			87.2	174.4	261.6	348 8	436.1	523.3	610.5	697.6
			4			0.78	1 19	1.66	2.19	2.77	3.55	4 34	5.22
88°	1.316	95°	1				1013.6	1582.2	2209.1	2909.2	3759.5	4645.6	5608 2
			2				927.1	1409.2	1949.6	2563.1	3326.9	4126.5	5002.5
			3				86.5	173.0	259.5	346.1	432.6	519.1	605.7
			4				0.89	1.36	1.88	2.48	3.23	4.02	4.89
Saturated Vapor Tension				1.201	1 408	1.645	1.916	2.225	2 576	2.975	3 425	3.933	4 504

Vapor Tensions, in inches of mercury.

Line, 1—Total thermal units.
" 2—Thermal units from evaporation.
Line, 3—Thermal units from heating air and vapor.
" 4—Wt. of water evaporated, in lbs.

TABLE GIVING THE PRESSURE IN POUNDS DUE TO THE HEIGHT OF A COLUMN OF WATER.

Head in Feet.	Pressure in Pounds per Square Inch.	Head in Feet.	Pressure in Pounds per Square Inch.	Head in Feet.	Pressure in Pounds per Square Inch.	Head in Feet.	Pressure in Pounds per Square In.
1	.43	20	8 66	55	23 83	90	38.90
2	.88	25	10 83	60	25 90	95	41.07
3	1 30	30	12.	65	28 06	130	43.33
4	1 74	35	15.16	70	30.55	125	54.17
5	2 16	40	17 33	75	32.72	150	65.
10	4 33	45	19 50	80	34 66	175	76 05
15	6 50	50	21 66	85	36.83	200	86.67

1 ℔ pressure per square inch is equivalent to a head of water of 2.3093 feet.
1 ℔ " " " " " " 27 71 in.
14.7 ℔s. or 1 atmosphere, " " " " 33.947 feet.
14.7 ℔s " " " " " 10 347 metres.
.0.433 ℔ " " " " " 1 foot.
43.3 ℔s. " " " " " 100 feet.

Memoranda Connected with Water.

1 cubic foot of water =62.5 pounds, or 7.48 U. S. gallons.
1 cubic inch of water=.036=pounds.
1 cubic foot of water=6.2355 Imp. gallons, or 7.48 U. S. gallons.

TABLE

Showing Refrigerating Effect of One Cubic Foot of Ammonia Gas at Different Condenser and Suction (Back) Pressures in B. T. Units.

Temperature of Gas in Degrees Fahr.	Corresponding Suction Pressure Pounds per Square Inch.	Temperature of the Liquid in Degrees Fahr.								
		65°	70°	75°	80°	85°	90°	95°	100°	105°
		Corresponding Condenser Pressure (gauge), Pounds per Square Inch.								
		103	115	127	139	153	168	184	200	218
	G. Pres.									
−27°	1	27.30	27.01	26.73	26.44	26.16	25.87	25.59	25.30	25.02
−20°	4	33.74	33.40	33.04	32.70	32.34	31.99	31.64	31.30	30.94
−15°	6	36.36	36.48	36.10	35.72	35.34	34.96	34.58	34.20	33.82
−10°	9	42.28	41.84	41.41	40.97	40.54	40.10	39.67	39 23	38.80
− 5°	13	48.31	47.81	47.32	46.82	46.33	45.83	45.34	44.84	44.35
0°	16	54.88	54.32	53.76	53.20	52.64	52 08	51.52	50.96	50.40
5°	20	61.50	60.87	60.25	59.62	59.00	58.37	57.75	57.12	56.50
10°	24	68.66	67.97	67.27	66.58	65.88	65.19	64.49	63.80	63.10
15°	28	75.88	75.12	74.35	73.59	72.82	72.06	71.29	70.53	69.76
20°	33	85.15	84.30	83.44	82.59	81.73	80.88	80.02	79.17	78.31
25°	39	95.50	94.54	93.59	92.63	91.68	90.72	89.97	88.81	87.86
30°	45	106.21	105.15	104.09	103.03	101.97	100.91	99.85	98.79	97.73
35°	51	115.69	114.54	123.39	112.24	111.09	109.94	108.79	107.64	106.49

SOLUBILITY OF GASES IN WATER AT ATMOSPHERIC PRESSURE.

1 Vol. Water Dissolves Vols. Gas.	32° Fahr.	39.2° Fahr.	50° Fahr.	60° Fahr.	70° Fahr.
Air	.0247	.0224	.0195	.0179	.0171
Ammonia	1049.6	941.9	812.8	727.2	654.0
Carbon Di-oxide	1.7987	1.5126	1.1847	1.0020	.9014
Sulphur Di-oxide	79.789	69.828	56.647	47.276	39.374
March Gas	.0545	.0499	.0437	.0391	.0350
Nitrogen	.0204	.0184	.0161	.0148	.0140
Hydrogen	.0193	.0193	.0191	.0193	.0193
Oxygen	.0411	.0372	.0325	.0299	.0284

WEIGHT OF AIR, VAPOR OF WATER, AND SATURATED MIXTURES OF AIR AND VAPOR AT DIFFERENT TEMPERATURES UNDER THE ORDINARY ATMOSPHERIC PRESSURE OF 29.921 INCHES OF MERCURY.

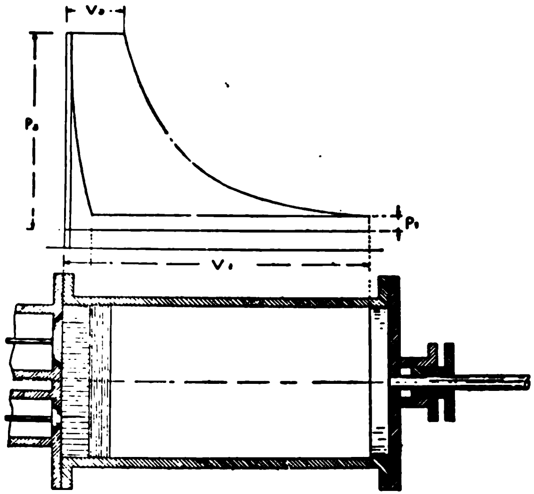
Temperature Farenheit.	Weight of a Cubic Foot of Dry Air at Different Temperature, in lbs.	Elastic Force of Vapor Inches of Mercury.	MIXTURE OF AIR SATURATED WITH VAPOR.				
			Elastic Force of the Air in Mixture of Air and Vapor. Inches of Mercury.	WEIGHT OF CUBIC FOOT OF THE MIXTURE OF AIR AND VAPOR.			Weight of Vapor Mixed with 1 Pound of Air in Pounds.
				Weight of the Air in Pounds.	Weight of the Vapor in Pounds.	Total Weight of Mixture in Pounds.	
0	.0864	.044	29.877	.0863	.000079	.086379	.00092
12	.0842	.074	29.849	.0840	.000130	.084130	.00155
22	.0824	.118	29.803	.0821	.000202	.082302	.00245
32	.0807	.181	29.740	.0802	.000304	.080504	.00379
42	.0791	.267	29.654	.0784	.000440	.078840	.00561
52	.0776	.388	29.533	.0766	.000627	.077227	.00819
62	.0761	.556	29.365	.0747	.000881	.075581	.01179
72	.0747	.785	29.136	.0727	.001221	.073921	.01680
82	.0733	1.092	28.829	.0706	.001667	.072267	.02361
92	.0720	1.501	28.420	.0684	.002250	.070717	.03289
102	.0707	2.036	27.885	.0659	.002997	.068897	.04547
112	.0694	2.731	27.190	.0631	.003946	.067046	.06253
122	.0682	3.621	26.300	.0599	.005142	.065042	.08584
132	.0671	4.752	25.169	.0564	.006639	.063039	.11771
142	.0660	6.165	23.756	.0524	.008473	.060873	.16170
152	.0649	7.930	21.991	.0477	.010716	.058416	.22465
162	.0638	10.099	19.822	.0423	.013415	.055715	.31713
172	.0628	12.758	17.163	.0360	.016682	.052682	.46338
182	.0618	15.960	13.961	.0288	.020536	.049336	.71300
192	.0609	19.828	10.093	.0205	.025142	.045642	1.22643
202	.0600	24.450	5.471	.0109	.030545	.041445	2.80230
212	.0591	29.921	0.000	.0000	.036820	.036820	Infinite

TABLE GIVING NUMBER OF CUBIC FEET OF GAS THAT MUST BE PUMPED PER MINUTE AT DIFFERENT CONDENSER AND SUCTION PRESSURES, TO PRODUCE ONE TON OF REFRIGERATION IN TWENTY-FOUR HOURS.

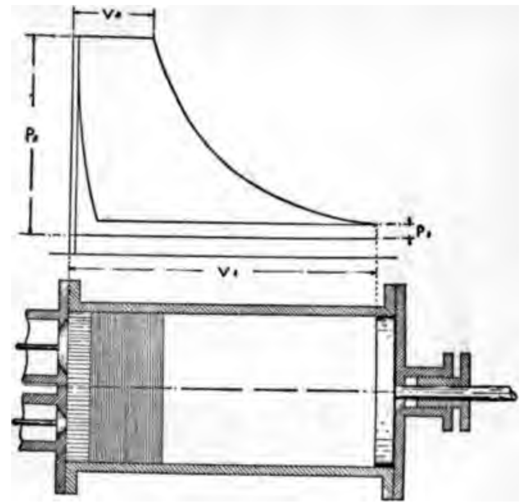
Temperature of Gas in Degrees F.	Corresponding Suction Pressure. Lbs. per sq. in.	Temperature of the Gas in Degrees F.								
		65°	70°	75°	80°	85°	90°	95°	100°	105°
		Corresponding Condenser Pressure (gauge), lbs. per sq. in.								
		103	115	127	139	153	168	184	200	218
	G. P.									
-27°	1	7.22	7.3	7.37	7.46	7.54	7.62	7.70	7.79	7.88
-20°	4	5.84	5.9	5.96	6.03	6.09	6.16	6.23	6.30	6.43
-15°	6	5.35	5.4	5.46	5.52	5.58	5.64	5.70	5.77	5.83
-10°	9	4.66	4.73	4.76	4.81	4.86	4.91	4.97	5.05	5.08
- 5°	13	4.09	4.12	4.17	4.21	4.25	4.30	4.35	4.40	4.44
0°	16	3.59	3.63	3.66	3.70	3.74	3.78	3.83	3.87	3.91
5°	20	3.20	3.24	3.27	3.30	3.34	3.38	3.41	3.45	3.49
10°	24	2.87	2.9	2.93	2.96	2.99	3.02	3.06	3.09	3.12
15°	28	2.59	2.61	2.65	2.68	2.71	2.73	2.76	2.80	2.82
20°	33	2.31	2.34	2.36	2.38	2.41	2.44	2.46	2.49	2.51
25°	39	2.06	2.08	2.10	2.12	2.15	2.17	2.20	2.22	2 24
30°	45	1.85	1.87	1.89	1.91	1.93	1.95	1.97	2.00	2.01
35°	51	1.70	1.72	1.74	1 76	1.77	1.79	1.81	1.83	1.85

PROPERTIES OF DIFFERENT LIQUIDS USED IN REFRIGERATING MACHINES.

Boiling Point. Degs. Fahr.	TENSION OF VAPOR IN POUNDS PER SQUARE INCH ABOVE ZERO.					
	Sulphuric Ether.	Sulphur Di-oxide.	Ammonia.	Methylic Ether.	Carbon Di-oxide.	Pictet Fluid.
- 40			10.22		....	....
- 31			13.23		....	....
- 22		5.56	16.95	11.15	....	....
- 13		7.23	21.51	13.85	251.9	....
- 4	1.30	9.27	27.04	17.06	292.9	13.5
+5	1.70	11.76	33.67	20.84	340.1	16.2
14	2.19	14.75	41.58	25.27	393.4	19.3
23	2.79	18.31	50.91	30.41	453.4	22.9
32	3.55	22.53	61.85	36.34	520.4	26.9
41	4.45	27.48	74.55	43.13	594.8	31.2
50	5.54	33.26	89.21	50.84	676.9	36.2
59	6.84	39.93	105.99	59.06	766.9	41.7
68	8.38	47.62	125.08	69.35	864.9	48.1
77	10.19	56.39	146.64	80.28	971.1	55.6
86	12.31	66.37	170.83	92.41	1085.6	64.1
95	14.76	77.64	197.83	....	1207.9	73.2
104	17.59	90.32	227.76	....	1338.2	82.9



HUMID GAS



DRY GAS

These diagrams are taken from the same compressor with dry gas and also with saturated vapor. The compression line of the diagram taken with dry gas will be seen to approach the adiabatic curve very closely, while in the other diagram the compression line approaches the isothermal curve. If a cylinder be filled with dry gas and another cylinder of the same size filled with humid gas at the same pressure (p^1 and p^1), both gases then compressed to the same pressure (p^2) the higher pressure (p^2) will be obtained sooner in the cylinder containing the dry gas than in the one containing the humid gas; at the same time there will be a much higher temperature in the dry gas cylinder than in the humid gas cylinder, necessitating the use of water jackets or other cooling processes on dry gas cylinders to reduce their superheat. It is quite evident therefore that the machines working with humid gas operate with a much lower temperature in the cylinder and, consequently, with a much lower pressure during the compression period and with less outlay of power to compress a given amount of ammonia than would be necessary with a machine using dry gas. The vertical shaded portion shows that part of the piston stroke at which the gas is compressed to its maximum pressure. The horizontally shaded portion indicates the amount of cylinder volume which is taken up by the re-expansion of such gas during the suction stroke as had filled the clearance space at the end of the compression stroke.

(See opposite page).

USEFUL DATA RELATING TO HEAT.

A "**British Thermal Unit**" is the heat necessary to raise one pound of water 1° F. at temperature of greatest density which is 39° to 40°.

One pound of carbon in burning will give 14,500 heat units.

Ordinarily good coal should give 14,000 units per pound combustible and 12,500 units per pound or coal.

In mechanical energy or work, a heat unit is equivalent to raising a weight of one pound to a height of 778 feet or 778 pounds to a height of one foot. The *mechanical equivalent of heat* then is 778 foot-pounds.

One pound of good coal contains sufficient energy to raise 9,725,000 pounds through one foot, or 97,250 pounds to a height of 100 feet.

If it were possible to convert the total heat of combustion into mechanical energy, then five horse-power would be obtained from each pound of coal burned per hour.

"**Sensible heat**" is that which is measured by a thermometer or is apparent in change of temperature, and for ordinary calculation each degree that water is heated may be considered one unit of heat for each pound of water, so that the weight of water multiplied by the increase of temperature equals the heat units absorbed.

"**Latent heat**" is that which is absorbed by a body in causing change of structure without increase of temperature. One pound of ice with a temperature of 32°, when melted will give one pound of water at a temperature of 32°, but to melt the ice heat is absorbed; this heat does not increase the temperature although 142 units are necessary. Water boils at a temperature of 212°. Each pound of water requires 966 units of heat to convert it into steam: the 212° is sensible heat, the 966° latent heat, these added together give the total heat of steam when water is evaporated in an open vessel = 1178 units sufficient to heat 1178 pounds of water 1°.

When water is evaporated under pressure the sensible heat increases while the latent heat decreases. At 100 pounds pressure the boiling water has a temperature of 338°, the latent heat is 879, the total heat 1217 units.

Specific Heat. The ratio of heat required to raise the temperature of a given substance one degree to that required to raise the temperature of the same weight of water one degree (from 39.1° Fahr., the temperature of maximum density) is called the *specific heat* of the substance.

A gallon of water evaporated at atmospheric pressure will produce about 200 cubic feet of steam.

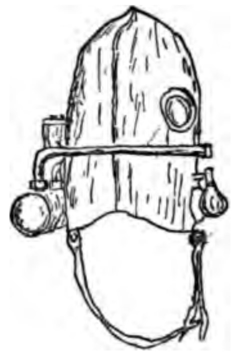
A gallon of water evaporated under a 27-inch vacuum will produce about 2000 cubic feet of vapor.

Water containing substances in solution has its boiling point raised.

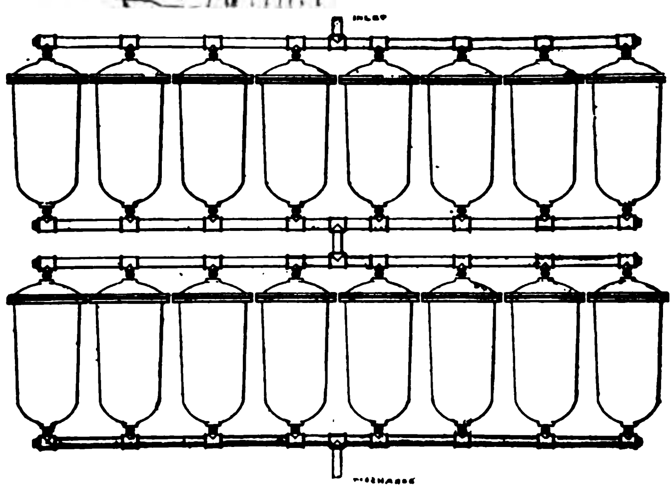
To determine the temperature at which any liquid will boil in a 27-inch vacuum, find the boiling temperature in an open vessel and deduct 100° Fahr.

One pound of water at 60° Fahr. requires 152° of sensible heat and 966° of latent heat to convert it into vapor. It requires approximately the same amount of fuel to evaporate, whether done in a vacuum or under pressure.

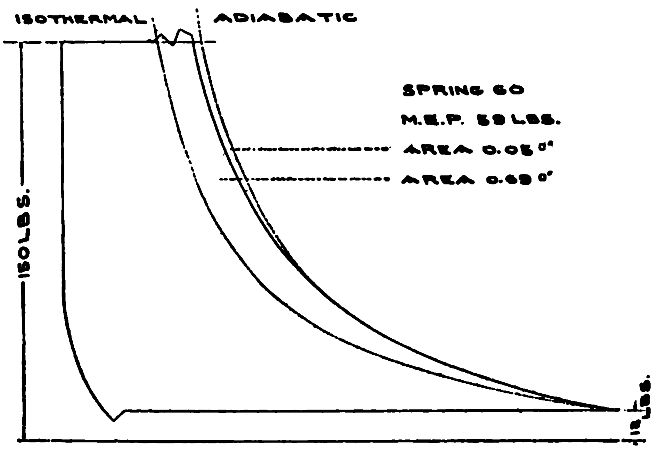
National
Smoke and
Ammonia
Helmet



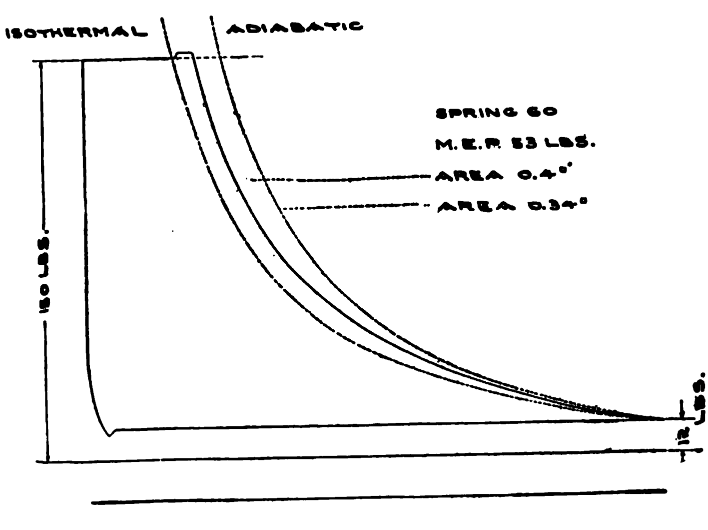
"Eveready" Smoke and
Ammonia Helmet



ihring Water Purifying System for five ton Ice plant; the upper tier are cleaners and the lower deodorizers.



DRY GAS.



SATURATED VAPOR.

For explanation, see opposite page.

MEAN PRESSURE OF DIAGRAM OF AMMONIA COMPRESSOR.

CONDENSER PRESSURE AND TEMPERATURE.

	p′	103	115	127	139	153	168	184	200	218
p	t°	65°	70°	75°	80°	85°	90°	95°	100°	105°
4	−20°	41.46	43.91	46.34	48.77	51.23	53.68	56.11	58.54	60.99
6	−15°	42.72	45.38	47.90	50.74	53.40	56.08	58.86	61.40	64.08
9	−10°	44.40	47.38	50.33	53.29	56.25	59.20	62.16	65.14	68.09
13	− 5°	45.86	49.15	52.42	55.70	58.97	62.25	65.53	68.81	72.08
16	0°	46.94	50.56	54.16	57.78	61.40	65.00	68.62	72.22	75.84
20	5°	47.74	51.73	55.70	59.68	63.67	67.66	71.62	75.61	79.61
24	10°	48.04	52.40	56.77	61.13	65.51	69.86	74.24	78.59	82.97
28	15°	47.88	52.67	57.44	62.23	67.02	71.81	76.60	81.39	86.18
33	20°	47.08	52.30	57.53	62.75	67.98	73.23	78.46	83.68	88.91
39	25°	45.06	51.34	57.05	62.75	68.46	74.17	79.88	85.58	91.29
45	30°	43.16	49.71	55.92	62.14	68.35	74.56	80.77	86 98	93.19
51	35°	40.52	47.26	54.02	60.76	67.52	74.28	81.02	87.78	94.52

KEY TO TABLE.

p—back, or suction, pressure. p′—head, or condenser, pressure. t°—temperature (Fahr.) of ammonia in condenser.

PROPERTIES OF AMMONIA LIQUOR

Line	% of NH_3 By Weight and Degree Béaume	0	5	10	15	20	25	30	35
1	1	206.3	223.6	234.9	247.4	256.2	263.8	270.4	277.1
2	1.84-11°B	201.4	219.3	231.6	243.0	251.7	259.4	266.4	272.7
3	2	201.1	218.5	230.8	242.1	250.9	258.6	265.5	271.9
4	3	195.8	213.2	225.5	236.6	245.6	253.3	260.2	266.8
5	3.80-12°B	191.5	208.8	221.0	232.3	241.0	248.7	255.7	262.0
6	.4	190.5	207.7	220.0	231.2	240.0	247.6	254.7	260.9
7	5	185.2	202.4	214.6	225.8	234.6	242.2	249.3	255.6
8	5.30-13°B	183.5	200.7	212.8	224.1	232.8	240.5	247.5	253.8
9	6	180.0	197.1	209.2	220.5	229.2	237.0	243.9	250.2
10	6.80-14°B	175.8	193.0	205.0	216.2	224.9	232.6	239.6	246.0
11	7	174.9	192.1	204.0	215.3	223.9	231.7	238.6	245.1
12	8	170.0	187.2	199.1	210.3	218.9	226.9	233.7	240.1
13	8.22-15°B	168.8	185.8	197.8	209.0	217.7	225.4	232.4	238.6
14	9	165.4	182.5	194.5	205.3	214.3	222.0	229.0	235.2
15	10-16°B	160.8	177.7	189.6	200.6	209.2	216.9	223.9	230.1
16	11	156.4	173.2	185.1	196.1	204.7	212.4	219.4	225.6
17	12	151.9	168.9	180.6	191.9	200.6	208.3	214.8	221.0
18	12.17-17°B	151.0	168.0	179.9	191.0	199.6	207.3	213.6	219.6
19	13	147.5	164.4	176.4	187.4	196.1	203.7	210.1	216.1
20	13.88-10°B	143.7	160.5	172.3	183.4	192.0	199.7	206.0	212.1
21	14	143.2	160.0	171.8	182.9	191.5	199.2	205.5	211.6
22	15	139.0	155.8	167.6	178.7	187.3	195.0	201.3	207.4
23	16	134.8	151.6	163.4	174.5	183.1	190.8	197.1	203.2
24	16.22-19°B	133.8	150.6	162.3	173.3	181.4	189.5	196.0	201.8
25	17	130.6	147.4	159.1	170.1	178.2	186.3	192.8	198.6
26	18.03-20°B	126.2	142.9	154.6	165.6	174.2	181.9	188.9	195.1
27	19	122.3	138.9	150.7	161.6	170.3	177.9	185.0	191.1
28	19.87-21°B	119.4	135.9	147.6	158.6	167.2	174.9	181.5	187.2
29	20	118.9	135.5	147.1	158.2	166.7	174.4	181.1	186.7
30	21	115.2	131.8	143.4	154.5	163.0	170.7	177.4	183.0
31	21.75-22°B	112.9	129.4	141.0	151.9	160.5	168.2	174.6	180.1
32	22	112.0	128.5	140.1	151.0	159.6	167.3	173.7	179.2
33	23.03-23°B	108.0	124.5	136.1	147.0	155.6	163.3	170.0	175.4
34	24.	114.8	121.3	132.9	143.8	152.4	160.1	166.8	172.2
35	24.99-24°B	101.5	117.8	129.3	140.1	148.6	156.3	163.0	168.4
36	26	98.3	114.6	126.2	136.9	145.5	153.1	159.8	165.3
37	27	95.1	111.4	123.1	133.7	142.3	150.0	156.6	162.1
38	27.66-25°B	93.0	109.4	121.0	131.7	140.1	147.9	154.5	159.9
39	28	92.0	108.3	120.0	130.6	139.1	146.8	153.4	158.9
40	29	88.9	105.2	117.0	127.5	136.0	143.8	150.3	155.8
41	29.60-26°B	87.0	103.3	114.7	125.4	133.9	141.6	148.2	153.8
42	30	85.8	102.1	113.5	124.2	132.7	140.4	147.0	152.6
43	31.05-27°B	82.6	98.8	110.2	120.9	129.4	137.1	143.5	149.2
44	32	80.1	96.2	107.6	118.3	126.8	134.5	140.9	146.6
45	33	77.4	93.5	104.9	115.6	124.1	131.8	138.7	143.9
46	33.25-28°B	76.5	92.6	103.9	114.6	123.1	130.8	137.8	143.0
47	34	74.6	90.7	102.0	112.7	121.2	128.9	135.9	141.1
48	35	72.0	88.1	99.4	110.1	118.6	126.3	133.3	138.5

John E. Starr's Tables of Properties of Aqua Ammonia, pages 629-632.

PROPERTIES OF AMMONIA LIQUOR

40	45	50	55	60	65	70	75	80	85	90	Line
282.8	288.1	292.9	297.5	301.9	306.3	310.4	314.4	318.2	321.8	325.2	1
278.4	283.7	288.5	293.1	297.5	301.8	306.0	310.0	313.8	317.4	320.8	2
277.6	282.8	287.7	292.2	296.7	300.9	305.2	309.2	312.9	316.6	320.0	3
272.3	277.5	282.4	286.9	291.4	295.6	300.0	303.9	307.6	311.3	314.7	4
267.7	272.9	277.8	282.4	286.8	291.1	295.3	299.3	303.1	306.7	310.1	5
266.7	271.8	276.7	281.4	285.7	290.1	294.2	298.3	302.1	305.6	309.1	6
261.4	266.5	271.4	276.1	280.4	284.8	288.9	293.0	296.3	300.3	303.8	7
259.6	264.8	270.2	274.8	279.2	283.5	287.7	291.7	295.5	299.1	302.5	8
256.1	261.2	266.7	271.2	275.6	280.0	284.1	288.2	291.9	295.5	299.0	9
251.8	257.0	262.1	266.7	271.1	275.4	279.6	283.6	287.4	291.0	294.4	10
250.8	256.1	261.1	265.8	270.1	274.5	278.6	282.7	286.4	290.1	293.5	11
245.9	251.2	266.2	260.8	265.2	269.6	273.7	281.7	281.5	285.2	288.6	12
244.2	249.3	254.1	258.7	263.1	267.4	271.6	275.6	279.4	283.0	286.4	13
240.8	245.9	250.7	255.3	259.7	264.0	268.2	272.2	276.0	279.6	283.0	14
235.5	240.6	245.4	250.0	254.4	258.7	262.9	266.9	270.7	274.3	277.7	15
231.0	236.1	240.9	244.5	249.9	254.2	258.4	262.4	266.2	268.8	273.2	16
226.4	231.5	236.4	240.0	245.4	249.8	253.9	257.9	261.7	264.3	268.7	17
225.0	230.3	234.4	239.0	243.4	247.7	251.9	255.4	259.7	263.3	266.7	18
221.4	226.8	230.8	235.5	239.9	244.2	248.4	251.8	256.2	259.8	263.1	19
217.6	222.7	227.2	231.8	236.2	240.5	244.0	248.7	252.5	256.1	259.5	20
217.1	222.2	226.7	231.3	235.7	240.0	243.5	248.2	252.0	255.6	259.0	21
212.9	218.0	222.5	227.1	231.5	235.8	239.3	244.0	247.8	251.4	254.8	22
208.7	213.8	218.3	222.9	227.3	231.6	235.1	239.8	243.6	247.2	250.6	23
207.2	212.3	217.1	221.7	226.1	230.4	234.6	238.6	242.4	246.0	249.4	24
203.9	209.1	213.9	218.5	222.9	227.2	231.4	235.4	239.2	242.8	246.2	25
200.7	205.7	209.5	214.1	218.5	222.8	227.0	231.0	234.8	238.4	241.8	26
196.8	201.7	205.6	210.1	214.6	218.8	223.1	227.0	230.9	234.4	237.9	27
192.5	197.5	202.3	206.9	211.3	215.6	219.8	223.8	227.6	231.2	234.6	28
192.1	197.0	201.9	206.4	210.8	215.2	219.3	223.4	227.1	230.7	234.1	29
188.4	193.3	198.2	202.7	207.1	211.5	215.6	219.7	223.3	227.6	230.4	30
185.3	190.3	195.1	199.7	204.1	208.4	212.6	216.6	220.4	224.0	227.4	31
184.4	189.4	194.2	198.8	203.2	207.5	211.7	215.7	219.5	223.1	226.5	32
180.2	185.2	190.0	194.6	199.0	203.3	207.5	211.5	215.3	218.9	222.3	33
177.0	182.0	186.8	191.4	195.8	200.1	204.2	208.3	212.1	215.7	219.1	34
173.6	178.6	183.2	187.8	192.2	196.5	200.7	204.7	208.5	212.1	215.5	35
170.4	175.5	179.9	184.7	189.1	193.3	197.5	201.6	205.3	208.9	212.2	36
167.2	172.4	176.7	181.5	185.9	190.2	194.3	198.4	202.2	205.7	209.0	37
165.1	170.3	174.4	178.9	183.3	187.6	191.8	195.8	199.6	203.2	206.6	38
164.0	169.3	173.3	177.9	183.2	186.6	190.7	194.8	198.5	202.2	205.6	39
161.0	166.2	170.2	174.8	180.2	183.5	187.6	191.8	195.4	199.1	202.6	40
159.0	164.3	168.1	172.7	178.1	181.4	185.6	189.6	193.4	197.0	200.4	41
157.8	163.1	166.9	171.6	176.9	180.2	184.4	188.4	192.2	195.8	199.2	42
154.5	159.8	163.6	168.3	173.5	177.0	181.2	185.2	189.0	192.6	196.0	43
151.9	157.2	161.0	165.7	170.9	174.4	178.6	182.6	186.4	190.0	193.4	44
149.2	154.5	158.3	163.0	168.2	171.7	175.9	179.9	183.7	187.3	190.7	45
148.3	153.6	157.4	162.1	167.3	170.8	175.0	179.0	182.8	186.4	189.8	46
146.4	151.7	155.5	160.2	165.4	168.9	173.1	177.1	180.9	184.5	187.9	47
143.8	149.1	152.9	157.6	162.8	166.3	170.5	174.5	178.3	181.9	185.3	48

PROPERTIES OF AMMONIA LIQUOR

Line	% of NH_3 By Weight and Degree Béaume	95	100	105	110	115	120	125	130
1	1	328.5	331.7	334.8	337.8	340.7	343.5	346.2	348.8
2	1.84–11°B	324.1	327.3	330.4	333.4	336.3	339.1	341.8	344.4
3	2	323.2	326.5	329.6	332.6	335.4	338.2	341.0	343.6
4	3	317.9	321.2	324.3	327.3	330.1	332.9	335.7	338.3
5	3.80–12°B	313.4	316.6	319.7	322.7	325.6	328.4	331.1	333.7
6	4	312.4	315.5	318.7	321.6	324.5	327.4	330.0	332.6
7	5	307.1	310.2	313.4	316.3	319.2	322.1	324.7	327.3
8	5.30–13°B	305.8	309.0	312.1	315.1	318.0	320.8	323.3	325.9
9	6	302.2	305.5	308.5	311.6	314.4	317.3	319.7	322.4
10	6.80–14°B	297.7	300.9	304.0	307.0	309.9	312.7	315.2	317.8
11	7	296.7	300.0	303.0	306.1	308.9	311.8	314.2	316.9
12	8	291.7	295.1	298.1	301.2	303.9	306.9	309.3	312.0
13	8.22–25°B	289.7	292.9	296.0	299.0	301.9	304.7	307.2	309.8
14	9	286.3	289.6	292.6	295.6	308.5	301.3	303.8	306.4
15	10–16°B	281.0	284.2	287.3	290.3	293.2	296.0	298.5	301.1
16	11	276.5	279.7	282.8	285.8	288.7	291.5	294.0	296.6
17	12	272.0	275.2	278.3	281.3	289.2	287.0	289.5	292.1
18	12.17–17°B	270.0	273.2	276.3	279.3	282.2	285.0	287.5	290.1
19	13	266.5	269.6	272.8	275.7	278.6	281.5	284.0	286.5
20	13.88–10°B	262.8	266.0	269.1	272.1	275.0	277.8	280.3	282.9
21	14	262.3	265.5	268.6	271.6	274.5	277.3	280.0	282.4
22	15	258.1	261.3	264.4	267.4	270.3	273.1	275.8	278.2
23	16	253.7	257.1	260.2	263.2	266.1	268.9	271.6	274.0
24	16.22–19°B	252.7	255.9	259.0	262.0	264.9	267.7	270.2	272.8
25	17	249.5	252.7	255.8	258.8	261.7	264.5	267.0	269.6
26	18.03–20°B	245.1	248.3	251.4	254.4	257.3	260.1	262.6	265.2
27	19	241.1	244.4	247.4	250.5	253.4	256.1	258.7	261.2
28	19.87–21°B	237.9	241.1	244.2	247.2	250.1	252.9	255.4	258.0
29	20	237.4	240.7	243.8	246.7	249.6	252.4	255.0	257.5
30	21	233.7	237.0	240.1	243.0	245.9	248.7	251.3	253.8
31	21.75–22°B	230.7	233.9	237.0	240.0	242.9	245.7	248.2	250.8
32	22	229.8	233.0	236.1	239.1	242.0	244.8	247.3	249.9
33	23.03–23°B	225.6	228.8	231.9	234.9	237.8	240.6	243.1	245.7
34	24	222.4	225.6	228.7	231.7	234.6	237.4	240.0	242.6
35	24.99–24°B	218.8	222.0	225.1	228.1	231.0	233.8	236.3	238.9
36	26	215.6	218.9	221.9	225.0	237.8	230.6	233.1	235.8
37	27	212.5	215.8	218.7	221.8	234.7	227.4	230.0	232.6
38	27.66–25°B	209.9	213.1	216.2	219.2	222.1	224.9	227.4	230.0
39	28	208.8	212.1	215.1	218.2	221.0	223.9	226.3	229.0
40	29	205.7	209.0	212.1	215.1	217.9	220.9	223.2	225.9
41	29.60–26°B	203.7	206.9	210.0	213.0	215.9	218.7	221.2	223.8
42	30	202.5	205.7	208.8	211.8	214.7	217.5	220.0	222.6
43	31–05.27°B	199.3	202.5	206.6	209.6	212.5	215.3	217.8	220.4
44	32	196.7	199.9	204.0	207.0	209.9	212.7	215.2	217.8
45	33	194.0	197.2	201.3	204.3	207.2	210.0	212.5	215.1
46	33.25–28°B	193.1	196.3	200.4	203.4	206.3	209.1	211.6	214.2
47	34	191.2	195.4	198.5	201.5	204.4	207.2	209.7	212.3
48	35	188.6	192.8	195.9	198.9	201.8	204.6	207.1	209.7

PROPERTIES OF AMMONIA LIQUOR

135	140	145	150	155	160	165	170	175	180	Line
351.3	353.7	356.0	358.2	360.3	362.3	364.2	366.1	367.4	369.5	1
346.9	349.3	351.6	353.8	355.9	357.9	359.8	361.7	363.5	365.1	2
346.1	348.2	350.8	352.9	355.1	357.1	358.9	360.9	362.7	364.3	3
340.8	342.9	345.5	347.6	349.8	351.8	353.6	355.6	357.4	359.0	4
336.2	338.6	340.9	343.1	345.2	347.2	349.2	351.1	352.8	354.4	5
335.2	337.6	339.8	342.1	344.1	346.2	348.2	350.1	351.7	353.4	6
329.9	332.3	334.5	336.8	338.8	340.9	342.9	344.9	346.4	348.1	7
328.4	330.8	333.1	335.3	337.4	339.4	341.3	343.2	345.0	346.6	8
324.8	327.3	329.5	331.8	333.8	335.9	337.7	339.6	341.4	343.7	9
320.3	322.7	325.0	327.2	329.3	331.3	333.3	335.2	336.9	338.5	10
319.3	321.8	324.0	321.3	328.3	330.4	332.3	334.1	335.9	336.6	11
314.3	316.9	319.1	321.4	327.3	325.5	327.4	329.2	330.9	331.7	12
312.3	314.7	317.0	319.2	321.3	323.3	325.3	327.2	328.9	330.5	13
308.9	311.3	313.6	315.8	317.9	319.9	321.8	323.7	325.5	327.2	14
303.6	306.0	308.3	310.5	312.6	314.6	316.6	318.5	320.2	321.8	15
299.2	301.5	303.8	305.0	308.2	310.2	312.1	314.0	315.8	317.5	16
294.7	297.0	299.3	300.5	303.8	305.8	307.6	309.5	311.3	313.0	17
292.6	295.0	297.3	299.5	301.6	303.6	305.6	307.5	309.2	310.8	18
289.1	291.5	293.7	296.0	298.1	300.1	302.0	304.0	305.7	307.3	19
285.4	287.8	290.1	292.3	294.4	296.4	298.3	300.1	302.0	303.6	20
284.9	287.3	289.6	291.8	293.9	295.9	297.8	299.6	301.5	303.1	21
280.7	283.1	285.4	287.6	289.7	291.7	293.6	295.4	297.3	298.9	22
276.5	279.9	281.2	283.4	285.5	287.5	289.4	291.3	293.1	294.7	23
275.3	277.7	280.0	282.2	284.3	286.3	288.3	290.3	292.0	293.6	24
272.1	274.5	276.8	278.0	281.1	283.1	285.1	287.1	288.8	290.4	25
267.7	270.1	272.4	274.6	276.7	278.7	280.7	282.6	284.3	285.9	26
263.8	266.1	268.5	270.6	272.8	274.7	276.8	278.6	280.4	282.0	27
260.5	262.9	265.2	267.4	269.5	271.5	273.5	275.4	277.1	278.7	28
260.1	262.4	264.7	266.9	269.0	271.1	273.0	275.0	276.6	278.2	29
256.4	259.7	261.0	263.2	265.3	267.4	269.3	271.3	272.9	274.5	30
253.3	255.7	258.0	260.2	262.3	264.3	266.3	268.2	269.9	271.5	31
252.4	254.8	257.1	259.3	261.4	263.4	265.4	267.3	269.0	270.6	32
248.2	250.6	252.9	255.1	257.2	259.2	261.2	263.1	264.8	266.4	33
246.0	247.4	249.7	251.9	254.0	256.0	257.9	259.8	261.5	263.1	34
241.4	243.8	246.1	248.3	250.4	252.4	254.4	256.3	258.0	259.6	35
238.3	240.6	242.9	245.2	247.3	249.3	251.2	253.1	254.9	256.5	36
235.2	237.4	239.8	242.1	244.2	246.1	248.0	249.9	251.7	253.4	37
232.5	234.9	237.2	239.4	241.5	243.5	245.3	247.2	248.9	250.5	38
231.4	233.9	236.1	238.4	240.4	242.5	244.3	246.1	247.8	248.5	39
228.4	230.8	233.0	235.4	237.3	239.4	241.3	243.1	244.8	245.5	40
226.3	228.7	231.0	233.2	235.3	237.3	239.3	241.2	242.9	244.5	41
225.1	227.5	229.8	232.0	234.1	236.1	238.1	240.0	241.7	243.3	42
222.9	225.3	227.6	229.8	231.9	233.9	235.8	237.5	239.2	240.8	43
220.3	222.7	225.0	227.2	229.3	231.3	233.2	234.9	236.5	238.2	44
217.6	220.0	222.7	224.5	226.6	228.6	230.5	232.2	233.8	235.5	45
216.7	219.1	221.8	223.6	225.6	227.5	229.3	231.1	232.8	234.4	46
214.8	217.2	219.9	221.7	223.7	225.6	227.4	229.2	230.9	232.5	47
212.2	214.6	217.3	219.1	221.1	223.8	224.8	226.8	228.2	231.3	48

PROPERTIES OF SATURATED AMMONIA GAS.

DE VOLSON WOOD AND GEORGE DAVIDSON.

Gauge Pressure Pounds per Square Inch	Absolute Pressure, Pounds per Square Inch	Temperature Degrees F.	Absolute Temperature Degrees F.	Latent Heat of Evaporation in Thermal Units	Volume of 1 Pound Vapor in Cubic Feet	Weight of 1 Cubic Foot of Vapor in Pounds	Volume of 1 Pound of Liquid in Cubic Feet	Weight of 1 Cubic Foot of Liquid in Pounds
—4.01	10.69	—40	420.66	579.67	24.38	.0410	.0234	42.589
—2.39	12.31	—35	425.66	576.68	21.32	.0469	.0236	42.337
—0.57	14.13	—30	430.66	573.69	18.69	.0535	.0237	42.123
+1.47	16.17	—25	435.66	570.68	16.44	.0608	.0238	41.858
3.75	18.45	—20	440.66	567.67	14.51	.0690	.0240	41.615
6.29	20.99	—15	445.66	564.64	12.83	.0779	.0241	41.374
9.10	23.80	—10	450.66	561.61	11.38	.0878	.0243	41.135
12.22	26.92	— 5	455.66	558.56	10.12	.0988	.0244	40.900
15.67	30.37	0	460.66	555.50	9.03	.1107	.0246	40.650
19.46	34.16	+ 5	465.66	552.43	8.07	.1240	.0247	40.404
23.64	38.34	10	470.66	549.35	7.23	.1383	.0249	40.160
28.24	42.94	15	475.66	546.26	6.49	.1541	.0250	39.920
33.25	47.95	20	480.66	543.15	5.84	.1711	.0252	39.682
38.73	53.43	25	485.66	540.03	5.27	.1897	.0253	39.432
44.72	59.42	30	490.66	536.91	4.76	.2099	.0255	39.200
51.22	65.92	35	495.66	533.78	4.31	.2318	.0256	38.940
58.29	72.99	40	500.66	530.63	3.91	.2554	.0258	38.684
65.96	80.66	45	505.66	527.47	3.56	.2809	.0260	38.461
74.26	88.96	50	510.66	524.30	3.24	.3084	.0261	38.226
83.22	97.92	55	515.66	521.12	2.96	.3380	.0263	37.994
92.89	107.59	60	520.66	517.93	2.70	.3697	.0265	37.736
103.33	118.03	65	525.66	514.73	2.48	.4039	.0266	37.481
114.49	129.19	70	530.66	511.52	2.27	.4401	.0268	37.230
126.52	141.22	75	535.66	508.29	2.09	.4791	.0270	36.995
139.40	154.10	80	540.66	505.05	1.92	.5205	.0272	36.751
153.18	167.88	85	545.66	501.81	1.77	.5649	.0273	36.509
167.92	182.62	90	550.66	498.55	1.64	.6120	.0275	36.258
183.65	198.35	95	555.66	495.29	1.51	.6622	.0277	36.023
200.42	215.12	100	560.66	492.01	1.39	.7153	.0279	35.778
218.28	232.98	105	565.66	488.72	1.289	.7757	.0281	
237.27	251.97	110	570.66	485.42	1.203	.8312	.0283	
258.7	272.14	115	575.66	482.41	1.121	.8912	.0285	
275.79	293.49	120	580.66	478.79	1.041	.9608	.0287	
301.46	316.16	125	585.66	475.45	.9699	1.0310	.0289	
325.72	340.42	130	590.66	472.11	.9051	1.1048	.0291	
350.46	365.16	135	595.66	468.75	.8457	1.1824	.0293	
377.52	392.22	140	600.66	465.39	.7910	1.2642	.0295	
405.79	420.49	145	605.66	462.01	.7408	1.3497	.0297	
435.5	450.20	150	610.66	458.62	.6946	1.4396	.0299	
466.84	481.54	155	615.66	455.22	.6511	1.5358	.0302	
499.70	514.50	160	620.66	451.81	.6128	1.6318	.0304	
534.84	549.04	165	625.66	448.39	.5765	1.7344	.0306	

One atmosphere in this table is equal to a pressure of a column of mercury 29.9 inches high.
Specific heat of ammonia gas and vapor at constant pressure . . = 0.508
The same at constant volume . . . . = 0.3913
Weight of 1 cubic foot liquid ammonia at 32 degrees Fahr. . . . =39.108 pounds
Volume of 1 pound liquid ammonia at 32 degrees Fahr. . . . . = 0.02557 cu. ft.
Specific heat of liquid ammonia . . . . =1.01235+0.003378 t,

CORRECTION FOR TEMPERATURE OF AQUA AMMONIA.

The Figures in Top Row Indicate Degrees Fahrenheit; those in Columns Beneath Give the Strength of Ammonia at 60°.

Degrees Baume.	60°	66°	67°	68°	72°	74°	76°	78°	81°	84°	88°	90°	92°	95°	96°	100°	102°	108°	109°
18	18	....	....	17¾	....	....	17½	....	....	17¼	....	....	17	....	....	16¾	....	16½	....
18¼	18¼	....	....	18	....	....	17¾	....	....	17½	....	....	17¼	....	....	17	....	16¾	....
18½	18½	....	....	18¼	....	....	18	....	....	17¾	....	....	17½	....	....	17¼	....	17	....
18¾	18¾	....	....	18½	....	....	18¼	....	....	18	....	....	17¾	....	....	17½	....	17¼	....
19	19	....	....	18¾	....	....	18½	....	....	18¼	....	....	18	....	....	17¾	....	17½	....
19¼	19¼	....	....	19	....	....	18¾	....	....	18½	....	....	18¼	....	....	18	....	17¾	....
19½	19½	....	....	19¼	....	....	19	....	....	18¾	....	....	18½	....	....	18¼	....	18	....
19¾	19¾	....	....	19½	....	....	19¼	....	....	19	....	....	18¾	....	....	18½	....	18¼	....
20	20	....	19¾	....	....	19½	....	....	19¼	....	19	....	....	18¾	....	....	18½	....	18¼
20¼	20¼	....	20	....	....	19¾	....	....	19¾	....	19¼	....	....	19	....	....	18¾	....	08½
20½	20½	....	20¼	....	....	20	....	....	19½	....	19½	....	....	19¼	....	....	19	....	18¾
20¾	20¾	....	20½	....	....	20¼	....	....	19¾	....	19¾	....	....	19½	....	....	19¼	....	19
21	21	....	20¾	....	....	20½	....	....	20	....	20	....	....	19¾	....	....	19½	....	19¼
21¼	21¼	....	21	....	....	20¾	....	....	20¼	....	20¼	....	....	20	....	....	19¾	....	19½
21½	21½	....	21¼	....	....	21	....	....	20½	....	20½	....	....	20¼	....	....	20	....	19¾
21¾	21¾	....	21½	....	....	21¼	....	....	20¾	....	20¾	....	....	20½	....	....	20¼	....	20
22	22	21¾	....	....	21½	....	....	21¼	....	21	....	20¾	....	....	20½	....	20¼	20	....
22¼	22¼	22	....	....	21¾	....	....	21½	....	21¼	....	21	....	....	20¾	....	20½	20¼	....
22½	22½	22¼	....	....	22	....	....	21¾	....	21½	....	21¼	....	....	21	....	20¾	20½	....
22¾	22¾	22½	....	....	22¼	....	....	22	....	21¾	....	21½	....	....	21¼	....	21	20¾	....
23	23	22¾	....	....	22½	....	....	22¼	....	22	....	21¾	....	....	21½	....	21¼	21	....
23¼	23¼	23	....	....	22¾	....	....	22½	....	22¼	....	22	....	....	21¾	....	21½	21¼	....
23½	23½	23¼	....	....	23	....	....	22¾	....	22½	....	22¼	....	....	22	....	21¾	21½	....

See continuation on opposite page.

Degrees Baume.	60°	66°	67°	68°	72°	74°	76°	78°	81°	84°	88°	90°	92°	95°	96°	100°	102°	108°	109°
23¾	23¾	....	23½	....	23¼	....	23	....	22¾	....	22½	....	22¼	....	22	....	21¾	....	21½
24	24	....	23¾	....	23½	....	23¼	....	23	....	22¾	....	22½	....	22¼	....	22	....	21¾
24¼	24¼	....	24	....	23¾	....	23½	....	23¼	....	23	....	22¾	....	22½	....	22¼	....	22
24½	24½	....	24¼	....	24	....	23¾	....	23½	....	23¼	....	23	....	22¾	....	22½	....	22¼
24¾	24¾	....	24½	....	24¼	....	24	....	23¾	....	23½	....	23¼	....	23	....	22¾	....	22½
25	25	....	24¾	....	24½	....	24¼	....	24	....	23¾	....	23½	....	23¼	....	23	....	22¾
25¼	25¼	....	25	....	24¾	....	24½	....	24¼	....	24	....	23¾	....	23½	....	23¼	....	23
25½	25½	25¼	....	25	....	24¾	....	24½	24¼	24	....	23¾	....	23½	....	23¼	23	22¾	....
25¾	25¾	25½	....	25¼	....	25	....	24¾	24½	24¼	....	24	....	23¾	....	23½	23¼	23	....
26	26	25¾	....	25½	....	25¼	....	25	24¾	24½	....	24¼	....	24	....	23¾	23½	23¼	....
26¼	26¼	26	....	25¾	....	25½	....	25¼	25	24¾	....	24½	....	24¼	....	24	23¾	23½	....
26½	26½	26¼	....	26	....	25¾	....	25½	25¼	25	....	24¾	....	24½	....	24¼	24	23¾	....
26¾	26¾	26½	....	26¼	....	26	....	25¾	25½	25¼	....	25	....	24¾	....	24½	24¼	24	....
27	27	26¾	....	26½	....	26¼	....	26	25¾	25½	....	25¼	....	25	....	24¾	24½	24¼	....
27¼	27¼	27	....	26¾	....	26½	....	26¼	26	25¾	....	25½	....	25¼	....	25	24¾	24½	....
27½	27½	27¼	....	27	....	26¾	....	26½	26¼	26	....	25¾	....	25½	....	25¼	25	24¾	....
27¾	27¾	27½	....	27¼	....	27	....	26¾	26½	26¼	....	26	....	25¾	....	25½	25¼	25	....
28	28	27¾	....	27½	....	27¼	....	27	26¾	26½	....	26¼	....	26	....	25¾	25½	25¼	....

The specific gravity of aqua ammonia changes with the temperature at which it is measured with the hydrometer. The readings are too high if the temperature of the ammonia is over 60° F., and too low if under. To ascertain the exact strength of ammonia at 60° F., make the corrections for temperature in accordance with the table, thus: 26½° ammonia, measured at a temperature of 80° F., is equal to 25¼° ammonia at a temperature of 60° F. (See page 369.)

PROPERTIES OF SALT BRINE.

CHLORIDE OF SODIUM.

1	2	3	4	5	6	7
Percentage of Salt by Weight.	Pounds of Salt per Gallon of Solution.	Degrees on Salometer at 60° F.	Weight per Gallon at 39° F. Lbs.	Specific Gravity at 39° F.	Specific Heat.	Freezing Point. Degrees Fahrenheit.
1	0.084	4	8.40	1.007	.992	+30.5
2	0.169	8	8.46	1.015	.984	29.3
2.5	0.212	10	8.50	1.019	.980	28.6
3	0.256	12	8.53	1.023	.976	27.8
3.5	0.300	14	8.56	1.026	.972	27.1
4	0.344	16	8.59	1.030	.968	26.6
5	0.433	20	8.65	1.037	.960	25.2
6	0.523	24	8.72	1.045	.946	23.9
7	0.617	28	8.78	1.053	.932	22.5
8	0.708	32	8.85	1.061	.919	21.2
9	0.802	36	8.91	1.068	.905	19.9
10	0.897	40	8.97	1.076	.892	18.7
12	1.092	48	9.10	1.091	.874	16.0
15	1.389	60	9.26	1.115	.855	12.2
20	1.928	80	9.64	1.155	.829	6.1
24	2.376	96	9.90	1.187	.795	1.2
25	2.488	100	9.97	1.196	.783	+ .5
26	2.610	...	10.04	1.204	.771	−1.1
29	.....	...	.....	.....	....	−4.7

(One authority gives values for specific heat about 2% lower.)

To determine the weight of one cubic foot of brine, multiply the values given in column 4 by 7.48.

To determine the weight of salt to one cubic foot of brine, multiply the values given in column 2 by 7.48.

KEY TO TABLE ON OPPOSITE PAGE.

t—Temperature in degrees Fahrenheit.
P—Absolute pressure in pounds per square inch.
H—Total in B. T. U. per pound of liquid.
h—Heat of liquid in B. T. U. per pound of liquid from 32° Fahrenheit.
L—Latent heat of vaporizing in B. T. U. per pound of liquid.
V—Volume in cubic feet of one pound of vapor.
W—Weight of vapor per cubic foot.
ϕ—Latent heat divided by temperature plus 460.

PROPERTIES OF CARBONIC ACID.

t	P	H	h	L	v	w	φ
−22	210	98.35	−37.80	136.15	.4138	2.321	.3108
−13	249	99.14	−32.51	131.65	.3459	2.759	.2945
−4	292	99.88	−26.91	126.79	.2901	3.265	.2785
5	342	100.58	−20.92	121.50	.2438	3.853	.2613
14	396	101.21	−14.49	115.70	.2042	4.535	.2441
23	457	101.81	−7.56	109.37	.1711	5.331	.2262
32	525	102.35	0.00	102.35	.1426	6.265	.2080
41	599	102.84	8.32	94.52	.1177	7.374	.1887
50	680	103.24	17.60	85.64	.0960	8.708	.1679
59	768	103.59	28.22	75.37	.0763	10.356	.1452
68	864	103.84	40.86	62.98	.0577	12.480	.1193
77	968	103.95	57.06	46.89	.0391	15.475	.0873
86	1.080	103.72	84.44	19.28	.0147	21.519	.0353

PROPERTIES OF SULPHUR DIOXIDE.

t	P	H	h	L	v	w	φ
−22	5.56	157.43	−19.56	176.99	13.17	.076	.4041
−13	7.23	158.64	−16.30	174.95	10.27	.097	.3914
−4	9.27	159.84	−13.05	172.89	8.12	.123	.3701
5	11.76	161.03	−9.79	170.82	6.50	.153	.3673
14	14.74	162.20	−6.53	168.73	5.25	.190	.3559
23	18.31	163.66	−3.27	166.63	4.29	.232	.3449
32	22.53	164.51	0.00	164.51	3.54	.282	.3344
41	27.48	165.65	3.27	162.38	2.93	.340	.3241
50	33.25	166.78	6.55	160.23	2.45	.406	.3142
59	39.33	167.90	9.83	158.07	2.07	.483	.3046
68	47.61	168.99	13.11	155.89	1.75	.570	.2952
77	56.39	170.09	16.39	153.70	1.49	.669	.2861
86	66.36	171.17	19.69	151.49	1.27	.780	.2774
95	77.64	172.24	22.98	149.26	1.09	.906	.2689
104	90.31	173.30	26.28	147.02	.91	1.046	.2607

For explanation, see opposite page.

PROPERTIES OF CHLORIDE OF CALCIUM BRINE.

Per Cent. of Anhydrous $Ca\ Cl_2$ by Weight.	Specific Gravity at 60° F.	Degrees Baumé at 60° F.	Degrees on Salometer at 60° F.	Specific Heat.	Freezing Point Degrees Fahr.	Ammonia Gauge Pressure when Freezing.
1	1.007	1	4	.996	+31.10	46.1 lbs.
2	1.015	2	8	.988	30.88	45.2 "
3	1.024	3	12	.980	29.48	44.1 "
4	1.032	4	16	.972	28.58	43.1 "
5	1.041	5.5	22	.964	27.68	42.0 "
6	1.049	6.5	26	.960	26.60	40.7 "
7	1.058	8	32	.936	25.52	39.4 "
8	1.067	9	36	.925	24.26	37.9 "
9	1.076	10	40	.911	22.82	36.4 "
10	1.085	11	44	.896	21.38	34.8 "
11	1.094	12	48	.890	19.76	33.0 "
12	1.103	13	52	.884	18.14	31.4 "
13	1.112	14.5	58	.876	16.34	29.6 "
14	1.121	15.5	62	.868	14.36	27.7 "
15	1.131	17	68	.860	12.20	25.8 "
16	1.140	18	72	.854	10.04	23.9 "
17	1.150	19	76	.849	7.52	21.7 "
18	1.159	20	80	.844	4.64	19.2 "
19	1.169	21	84	.839	+1.76	17.0 "
20	1.179	22	88	.834	—1.48	14.6 "
21	1.189	23	92	.825	4.90	12.3 "
22	1.199	24	96	.817	8.68	9.9 "
23	1.209	25	100	.808	12.64	7.6 "
24	1.219	26	104	.799	17.14	5.2 "
25	1.229	27	108	.790	21.82	2.9 "
26	1.240	28	112	.778	27.04	0.6 "
27	1.250	29	116	.769	32.62	3.1" vac.
28	1.261	30	120	.757	39.28	7.7" "
29	1.272	31	....	....	46.30	12.2" "
30	1.283	32	....	....	54.40	17.3" "
31	1.294	33	....	....	52.42	16.0" "
32	1.305	34	....	....	39.28	7.7" "
33	1.316	35	....	....	25.24	1 5" lbs.
34	1.327	35.5	....	....	—9.76	9.3 "
35	1.338	36.5	....	....	+2.84	17.8 "
36	1.349	37.5	....	....	14.36	27.7 "

Some authorities give lower values for specific heat, for instance 2% lower for 1.170 spec. gravity, and again, 7% lower in the case of 1.200 spec. gravity. Some give higher freezing points than here stated, 15° F. for 15%, +5° for 20%, —8° for 25% solution.

Since Commercial Fused $Ca\ Cl_2$ contains at least 25% moisture, more of it is required than stated in table; so that for a 20% solution, for example, at least $\frac{20}{75}$ = 26.7% will be required.

TABLE OF PROPERTIES OF SATURATED STEAM.

Gauge Pressure per Square Inch, in Pounds	Pressure Above Vacuum per Square Inch in Pounds	Temperature in Degrees F.	Total Heat in Heat Units at 32 Degrees F.	Heat in Liquid from 32 Degrees in Heat Units	Heat of Vaporization or Latent Heat in Heat Units	Density or Weight of 1 Cubic Foot in Pounds	Volume of 1 Pound in Cubic Feet	Factor of Equivalent Evaporation at 212 Degrees F.
......	1	101.99	1113.1	70.0	1043.0	0.00299	334.50	0.9661
......	2	126.27	1120.5	94.4	1026.1	0.00576	173.60	.9738
......	3	141.62	1125.1	109.8	1015.3	0.00844	118.50	.9786
......	4	153.09	1128.6	121.4	1007.2	0.01107	90.33	.9822
......	5	162.34	1131.5	130.7	1000.8	0.01366	73.21	.9852
......	6	170.14	1133.8	138.6	995.2	0.01622	61.65	.9876
......	7	176.80	1135.9	145.4	990.5	0.01874	53.39	.9897
......	8	182.92	1137.7	151.5	986.2	0.02125	47.06	.9916
......	9	188.33	1139.4	156.9	982.5	0.02374	42.12	.9934
......	10	193.25	1140.9	161.9	979.0	0.02621	38.15	.9949
.0	14	212.00	1146.6	180.7	966.0	0.03793	26.78	1.0000
.03	15	213.03	1146.9	181.8	965.1	0.03826	26.14	1.0003
5.3	20	227.95	1151.5	196.9	954.6	0.05023	19.91	1.0051
10.3	25	240.04	1155.1	209.1	946.0	0.06199	16.13	1.0099
15.3	30	250.27	1158.3	219.4	938.9	0.07360	13.59	1.0129
20.3	35	259.19	1161.0	228.4	932.6	0.08508	11.75	1.0157
25.3	40	267.13	1163.4	236.4	927.0	0.09644	10.37	1.0182
30.3	45	274.29	1165.6	243.6	922.0	0.1077	9.285	1.0205
35.3	50	280.85	1167.6	250.2	917.4	0.1188	8.418	1.0225
40.3	55	286.89	1179.4	256.3	913.1	0.1299	7.698	1.0245
45.3	60	292.51	1171.2	261.9	909.3	0.1409	7.097	1.0263
50.3	65	297.77	1172.7	267.2	905.9	0.1519	6.583	1.0280
55.3	70	302.71	1174.3	272.2	902.1	0.1628	6.143	1.0295
60.3	75	307.38	1175.7	276.9	898.8	0.1736	5.760	1.0309
65.3	80	311.80	1177.0	281.4	895.6	0.1843	5.426	1.0323
70.3	85	316.02	1178.3	285.8	892.5	0.1951	5.126	1.0337
75.3	90	320.04	1179.6	290.0	889.6	0.2058	4.859	1.0350
80.3	95	323.89	1180.7	294.0	886.7	0.2165	4.619	1.0362
85.3	100	327.58	1181.9	297.9	884.0	0.2271	4.403	1.0374
90.3	105	331.13	1182.9	301.6	881.3	0.2378	4.205	1.0385
95.3	110	334:56	1184.0	305.2	878.8	0.2484	4.026	1.0396
100.3	115	337.86	1185.0	308.7	876.3	0.2589	3.862	1.0406
105.3	120	341.05	1186.0	312.0	874.0	0.2695	3.711	1.0416
110.3	125	344.13	1186.9	315.2	871.7	0.2800	3.571	1.0426
115.3	130	347.12	1187.8	318.4	869.4	0.2904	3.444	1.0435
125.3	140	352.85	1189.5	324.4	865.1	0.3113	3.212	1.0453
135.3	150	358.26	1191.2	330.0	861.2	0.3321	3.011	1.0470
145.3	160	363.40	1192.8	335.4	857.4	0.3530	2.833	1.0486
155.3	170	368.29	1194.3	340.5	853.8	0.3737	2.676	1.0502
165.3	180	372.07	1195.7	345.4	850.3	0.3945	2.535	1.0517
175.3	190	377.44	1197.1	350.1	847.0	0.4153	2.408	1.0531
185.3	200	381.73	1198.4	354.6	843.8	0.4359	2.294	1.0545
210.3	225	391.79	1201.4	365.1	836.3	0.4876	2.051	1.0576
235.3	250	400.99	1204.2	374.7	829.5	0.5393	1.854	1.0605
260.3	275	409.50	1206.8	383.6	823.2	0.5913	1.691	1.0632
285.3	300	417.42	1209.3	391.9	817.4	0.644	1.553	1.0657
310.3	325	424.82	1211.5	399.6	811.9	0.696	1.437	1.0680
335.3	350	431.90	1213.7	406.9	806.8	0.728	1.337	1.0703
360.3	375	438.40	1215.7	414.2	801.5	0.800	1.250	1.0724
385.3	400	445.15	1217.7	421.4	796.3	0.853	1.172	1.0745
485.3	500	466.57	1224.2	444.3	779.9	1.065	0.939	1.0812

SIZES OF CHIMNEYS

Diameter in Inches.	HEIGHT OF CHIMNEYS AND COMMERCIAL HORSE POWER.											Side of Square Inches.	Effective Area, Square Feet.	Actual Area, Square Feet.
	50 ft.	60 ft.	70 ft.	80 ft.	90 ft.	100 ft.	110 ft.	125 ft.	150 ft.	175 ft.	200 ft.			
18	23	25	27									16	0.97	1.77
21	35	38	41									19	1.47	2.41
24	49	54	58	62								22	2.08	3.14
27	65	72	78	83								24	2.78	3.98
30	84	92	100	107	113							27	3.58	4.91
33		115	125	133	141							30	4.48	5.94
36		141	152	163	173	182						32	5.47	7.07
39			183	196	208	219						35	6.57	8.30
42			216	231	245	258	271					38	7.76	9.62
48				311	330	348	365	389				43	10.44	12.57
54				363	427	449	472	503	551			48	13.51	15.90
60				505	536	565	593	632	692	748		54	16.98	19.64
66					658	694	728	776	849	918	981	59	20.83	23.76
72					792	835	876	934	1023	1105	1181	64	25.08	28.27
78						995	1038	1107	1212	1310	1400	70	29.73	33.18
84						1163	1214	1294	1418	1531	1637	75	34.76	38.48
90						1344	1415	1496	1639	1770	1893	80	40.19	44.18
96						1537	1616	1720	1876	2027	2167	86	46.01	50.27
102								1946	2133	2303	2462	90	52.23	56.75
108								2192	2402	2594	2773	96	58.83	63.62
114								2459	2687	2903	3003	101	65.83	70.88
120									2990	3230	3452	106	73.22	78.54
126									3308	3573	3820	112	81.00	86.59
132									3642	3935	4205	117	89.19	95.03
138									3091	4311	4608	122	97.75	103.86
144									4357	4707	5031	127	106.72	113.10

EVAPORATION OF WATER INTO STEAM.

A cubic inch of water evaporated under ordinary atmospheric pressure is converted into a cubic *foot* of steam (approximately).

Steam at atmospheric pressure flows into a *vacuum* at the rate of about 1550 feet per second, and into the *atmosphere* at the rate of 650 feet per second.

27,222 cubic feet of steam weigh 1 pound; 13,817 cubic feet of air weigh 1 pound.

The best designed boilers, well set, with good draft and skillful firing will evaporate from 7 to 10 lbs. of water per pound of first-class coal. The average result is below this.

One square foot of grate will consume on an average of 12 lbs. of coal per hour.

Steam engines, in economy, vary from 16 to 60 lbs. of feed water, and from 2 to 7 lbs. of coal per hour per indicated horse power.

Condensing engines require from 20 to 30 gallons of water to condense the steam represented by every gallon of water evaporated—approximately for most engines, we say, from 1 to 1½ gallons per minute per I. H. P. Jet condensers do not require quite as much water for condensing as surface condensers.

VALUE OF WOOD FUEL.

1 cord of air-dried hickory or hard maple weighs about 4500 lbs. and is equal to about 2000 lbs. coal.

1 cord of air-dried white oak weighs about 3850 lbs. and is equal to about 1715 lbs. coal.

1 cord of air-dried beech, red oak, or black oak weighs about 3250 lbs. and is equal to about 1450 lbs. of coal.

1 cord of air-dried poplar, whitewood, chestnut, or elm weighs about 2350 lbs. and is equal to about 1050 lbs. coal.

1 cord of air-dried average pine weighs about 2000 lbs. and is equal to about 625 lbs. coal.

HORSE POWER REQUIRED TO PRODUCE ONE TON OF REFRIGERATION.

CONDENSER PRESSURE AND TEMPERATURE.

REFRIGERATOR PRESSURE AND TEMP.	p	103	115	127	139	153	168	184	200	218
p	t	65°	70°	75°	80°	85°	90°	95°	100°	105°
4	—20°	1.0584	1.1304	1.2051	1.2832	1.3611	1.4427	1.5251	1.6090	1.6910
6	—15°	.9972	1.0692	1.1450	1.2221	1.3001	1.4101	1.4609	1.5458	1.6300
9	—10°	.9026	.9777	1.0453	1.1183	1.1926	1.2602	1.3471	1.4352	1.5093
12	— 5°	.8184	.8833	.9537	1.0230	1.0935	1.1679	1.2437	1.3209	1.3964
16	0°	.7352	.8008	.8648	.9328	1.0019	1.0718	1.1467	1.2194	1.2547
20	5°	.6665	.7312	.7946	.8593	.9278	.9978	1.0656	1.1381	1.2121
24	10°	.5915	.6629	.7257	.7894	.8545	.9205	.9911	1.0595	1.1294
28	15°	.5410	.5998	.6641	.7276	.7924	.8553	.9224	.9943	1.0603
33	20°	.4745	.5340	.5923	.6716	.7148	.7796	.8420	.9031	.9736
39	25°	.4103	.4659	.5227	.5804	.5992	.7022	.7667	.8289	.8922
45	30°	.3509	.4056	.4612	.5178	.5755	6353	.6944	.7590	.8172
51	35°	.3005	.3546	.4101	.4666	.5214	5804	.6398	.7009	.7629

Table for Single Leather, Four-Ply Rubber and Four-Ply Cotton Belting, Belts not Overloaded

1 inch wide, 800 feet per minute — 1 horse power.

Speed in ft. pr minute	WIDTH OF BELTS IN INCHES.											
	2	3	4	5	6	8	10	12	14	16	18	20
	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.
400	1	1½	2	2½	3	4	5	6	7	8	9	10
600	1½	2¼	3	3¾	4½	6	7½	9	10½	12	13½	15
800	2½	3	4	5	6	8	10	12	14	16	18	20
1000	3	3¾	5	6¼	7½	10	12½	15	17½	20	22½	25
1200	3	4½	6	7½	9	12	15	18	21	24	27	30
1500	3¾	5⅝	7½	9⅜	11¼	15	18¾	22½	26¼	30	33¾	37½
1800	4½	6¾	9	11¼	13½	18	22½	27	31½	36	40½	45
2000	5	7½	10	12½	15	20	25	30	35	40	45	50
2400	6	9	12	15	18	24	30	36	42	48	54	60
2800	7	10½	14	17½	21	28	35	42	49	56	63	70
3000	7½	11¼	15	18¾	22½	30	37½	45	52½	60	67½	75
3500	8¾	13	17½	22	26	35	44	52½	61	70	79	88
4000	10	15	20	25	30	40	50	60	70	80	90	100
4500	11¼	17	22½	28	34	45	57	69	78	90	102	114
5000	12½	19	25	31	37½	50	62½	75	87½	100	112	125

Double leather, six-ply rubber or six-ply cotton belting will transmit 50 to 75 per cent more power than is shown in this table. (1 inch wide, 550 feet per minute — 1 horse power).

WROUGHT IRON WELDED STEAM, GAS AND WATER PIPE—Table of Standard Dimensions

Diameter.			Thickness.	Circumference.		Transverse Areas.			Length of Pipe per Square Foot of		Length of Pipe containing One Cubic Foot.	Weight per Foot of Length.	No of Thr'ads per Inch of Screw.	Contents in Gals. per Foot of Length	Weight of Water per Foot of Length
Nominal Internal.	Actual External.	Actual Internal.		External.	Internal.	External.	Internal.	Metal.	External Surface.	Internal Surface.					
Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Sq. Inch.	Sq. Inch.	Sq. Inch.	Feet.	Feet.	Feet.	Lbs.		Gallons.	Lbs.
1/8	.405	.27	.068	1.272	.848	.129	.0573	.0717	9.44	14.15	2513.	.241	27	.0006	.005
1/4	.54	.364	.088	1.696	1.144	.229	.1041	.1249	7.075	10.49	1383.3	.42	18	.0026	.021
3/8	.675	.494	.091	2.121	1.552	.358	.1917	.1663	5.657	7.73	751.2	.559	18	.0057	.047
1/2	.84	.623	.109	2.639	1.957	.554	.3048	.2492	4.547	6.13	472.4	.837	14	.0102	.085
3/4	1.05	.824	.113	3.299	2.589	.866	.5333	.3327	3.637	4.635	270.	1.115	14	.0230	.190
1	1.315	1.048	.134	4.131	3.292	1.358	.8626	.4954	2.904	3.645	166.9	1.668	11½	.0408	.349
1¼	1.66	1.38	.14	5.215	4.335	2.164	1.496	.668	2.301	2.768	96.25	2.244	11½	.0638	.527
1½	1.9	1.611	.145	5.969	5.061	2.835	2.038	.797	2.01	2.371	70.66	2.678	11½	.0918	.760
2	2.375	2.067	.154	7.461	6.494	4.43	3.356	1.074	1.608	1.848	42.91	3.609	11½	.1632	1.356
2½	2.875	2.468	.204	9.032	7.753	6.492	4.784	1.708	1.328	1.547	30.1	5.739	8	.2550	2.116
3	3.5	3.067	.217	10.996	9.636	9.621	7.388	2.243	1.091	1.245	19.5	7.536	8	.3673	3.049
3½	4.	3.548	.226	12.566	11.146	12.566	9.887	2.679	.955	1.077	14.57	9.001	8	.4998	4.155
4	4.5	4.026	.237	14.137	12.648	15.904	12.73	3.174	.849	.949	11.31	10.665	8	.6528	5.405
4½	5.	4.508	.246	15.708	14.162	19.635	15.961	3.674	.764	.848	9.02	12.34	8	.8263	6.851
5	5.563	5.045	.259	17.477	15.849	24.306	19.99	4.316	.687	.757	7.2	14.502	8	1.020	8.500
6	6.625	6.065	.28	20.813	19.054	34.472	28.888	5.584	.577	.63	4.98	18.762	8	1.469	12.312
7	7.625	7.023	.301	23.955	22.063	45.664	38.738	6.926	.501	.544	3.72	23.271	8	1.999	16.662
8	8.625	7.982	.322	27.096	25.076	58.426	50.04	8.386	.443	.478	2.88	28.177	8	2.611	21.750
9	9.625	8.937	.344	30.238	28.076	72.76	62.73	10.03	.397	.427	2.29	33.701	8	3.300	27.500
10	10.75	10.019	.366	33.772	31.477	90.763	78.839	11.924	.355	.382	1.82	40.065	8	4.081	34.000
11	12.	11.25	.375	37.699	35.343	113.098	99.402	13.696	.318	.339	1.456	45.95	8	......	......
12	12.75	12.	.375	40.055	37.7	127.677	113.098	14.579	.299	.319	1.27	48.985	8	......	......
	14.	13.25	.375	43.982	41.626	153.938	137.88	16.051	.273	.288	1.04	53.922	8	......	......
	15.	14.25	.375	47.124	44.768	176.715	159.485	17.23	.255	.268	.903	57.893	8	......	......
	16.	15.25	.375	50.265	47.909	201.062	182.655	18.407	.239	.250	.788	61.77	8	......	......
....	18.	17.25	.375	56.549	54.192	254.47	233.706	20.764	.212	.221	.616	69.66	....	......	......
....	20.	19.25	.375	62.832	60.476	314.16	291.04	23.12	.191	.198	.495	77.57	....	......	......
....	22.	21.25	.375	69.115	66.759	380.134	354.657	25.477	.174	.179	.406	85.47	....	......	......
....	24.	23.25	.375	75.398	73.042	452.39	424.558	27.832	.159	.164	.339	93.37	....	......	......

1" and below are butt-welded and tested to 300 lbs. hydraulic pressure. 1¼" and above are lap-welded and tested to 500 lbs. hydraulic pressure.

Pipes larger than 12 inch are called "Large O. D. Pipes" and are made in the following thicknesses:

14, 15, 16, 17, and 18 inches Outside Diameter, $\frac{1}{4}$, $\frac{5}{16}$, $\frac{3}{8}$, $\frac{7}{16}$, and $\frac{1}{2}$ inch thick.

20, 22, and 24 inches Outside Diameter, $\frac{5}{16}$, $\frac{3}{8}$, $\frac{7}{16}$, and $\frac{1}{2}$ inch thick.

26 and 28 inches Outside Diameter, $\frac{3}{8}$, $\frac{7}{16}$, and $\frac{1}{2}$ inch thick.

30 inches Outside Diameter, $\frac{7}{16}$ and $\frac{1}{2}$ inch thick.

Table of Comparative Capacities of Pipes of Standard Sizes, Showing the Number of Times the Area of One Pipe is Contained in that of a Larger

	⅛	¼	⅜	½	¾	1	1¼	1½	2	2½	3	3½	4	5	6	7	8	9	10
⅛	1.																		
¼	1.9	1.																	
⅜	3.3	1.8	1.																
½	5.3	2.9	1.5	1.															
¾	9.3	5.2	2.7	1.7	1.														
1	14.7	7.7	4.1	2.6	1.6	1.													
1¼	26.2	14.3	7.8	4.9	2.8	1.6	1.												
1½	35.6	19.5	10.6	6.6	3.8	2.4	1.3	1.											
2	58.6	32.2	17.5	11.0	6.9	3.9	2.2	1.6	1.										
2½	83.6	44.6	25.0	15.7	9.0	5.5	3.2	2.3	1.4	1.									
3	129.1	71.0	38.5	24.2	13.8	8.5	5.0	3.6	2.2	1.5	1.								
3½	172.8	95.0	51.6	32.4	18.5	11.4	6.6	4.8	2.9	2.0	1.3	1.							
4	222.5	122.3	66.4	41.7	23.8	14.7	8.5	6.2	3.8	2.6	1.7	1.3	1.						
5	349.4	192.0	104.3	65.6	37.4	23.1	13.3	9.8	5.9	4.1	2.7	2.0	1.5	1.					
6	505.0	277.5	150.7	94.7	54.1	33.4	19.3	14.1	8.6	6.0	3.9	2.9	2.2	1.4	1.				
7	677.2	372.1	202.2	127.0	71.3	44.9	25.9	19.0	11.5	8.1	5.2	3.9	3.0	1.9	1.3	1.			
8	878.3	480.7	261.2	164.1	93.8	58.0	34.5	24.5	14.9	10.4	6.7	5.0	3.9	2.5	1.7	1.3	1.		
9	1112.4	611.2	332.1	208.7	170.3	73.4	42.7	31.2	19.0	13.3	8.7	6.4	5.0	3.1	2.2	1.6	1.2	1.	
10	1378.3	757.3	411.5	258.6	147.8	91.3	52.7	38.6	23.5	16.5	10.[illegible]	7.9	6.2	3.9	2.7	2.0	1.5	1.2	1.

Wrought Iron Welded Extra Strong Pipe—Table of Standard Dimensions

Diameter			Thickness Inches	Nearest Wire Gauge Number	Circumference		Transverse Areas			Length of Pipe per Square Foot of		Nominal Weight per Foot Pounds
Nominal Internal Inches	Actual External Inches	Actual Internal Inches			External Inches	Internal Inches	External Square Inches	Internal Square Inches	Metal Square Inches	External Surface Feet	Internal Surface Feet	
1/8	.405	.205	.1	12½	1.272	.644	.129	.033	.096	9.433	18.632	.29
1/4	.54	.294	.123	11	1.696	.924	.229	.068	.161	7.075	12.986	.54
3/8	.675	.421	.127	10¼	2.121	1.323	.358	.139	.219	5.657	9.07	.74
1/2	.84	.542	.149	9	2.639	1.703	.554	.231	.323	4.547	7.046	1.09
3/4	1.05	.736	.157	8½	3.299	2.312	.866	.452	.414	3.637	5.109	1.39
1	1.315	.951	.182	7	4.131	2.988	1.358	.71	.648	2.904	4.016	2.17
1¼	1.66	1.272	.194	6½	5.215	3.996	2.164	1.271	.893	2.301	3.003	3.
1½	1.9	1.494	.203	6	5.969	4.694	2.835	1.753	1.082	2.01	2.556	3.63
2	2.375	1.933	.221	5	7.461	6.073	4.43	2.935	1.495	1.608	1.975	5.02
2½	2.875	2.315	.28	2	9.032	7.273	6.492	4.209	2.283	1.328	1.649	7.67
3	3.5	2.892	.304	1	10.996	9.085	9.621	6.569	3.052	1.091	1.328	10.25
3½	4.	3.358	.321	0	12.566	10.549	12.566	8.856	3.71	.955	1.137	12.47
4.	4.5	3.818	.341	0	14.137	11.995	15.904	11.449	4.455	.849	1.	14.97
5	5.563	4.813	.375	00	17.477	15.120	24.306	18.193	6.12	.687	.793	20.54
6	6.625	5.75	.437	000	20.813	18.064	34.472	25.967	8.505	.577	.664	28.58

Double Extra Strong Pipe

Nominal Internal Inches	Actual External Inches	Actual Internal Inches	Thickness Inches	Nearest Wire Gauge Number	External Circumference Inches	Internal Circumference Inches	External Square Inches	Internal Square Inches	Metal Square Inches	External Surface Feet	Internal Surface Feet	Nominal Weight per Foot Pounds
1/2	.84	.244	.298	1	2.639	.766	.554	.047	.507	4.547	15.667	1.7
3/4	1.05	.422	.314	1	3.299	1.326	.866	.139	.727	3.637	9.049	2.44
1	1.315	.587	.364	00	4.131	1.844	1.358	.271	1.087	2.904	6.508	3.65
1¼	1.66	.885	.388	00	5.215	2.78	2.164	.615	1.549	2.304	4.317	5.2
1½	1.9	1.088	.406	000	5.969	3.418	2.835	.93	1.905	2.01	3.511	6.4
2	2.375	1.491	.442	0000	7.461	4.684	4.43	1.744	2.686	1.608	2.561	9.02
2½	2.875	1.755	.560	9/16—	9.032	5.513	6.492	2.419	4.073	1.328	2.176	13.68
3	3.5	2.284	.608	5/8—	10.996	7.175	9.621	4.097	5.524	1.091	1.672	18.56
3½	4.	2.716	.642	5/8+	12.566	8.533	12.566	5.794	6.772	.955	1.406	22.75
4	4.5	3.136	.682	11/16—	14.137	9.852	15.904	7.724	8.18	.849	1.217	27.48
5	5.563	4.063	.75	3/4	17.477	12.764	24.306	12.965	11.34	.687	.940	38.12
6	6.625	4.875	.875	7/8	20.813	15.815	34.472	18.666	15.896	.577	.784	53.11

Contents in Cubic Feet of Cylinders One Inch Long.

Diam.	0	¼	½	¾	Diam.
1"	.00045	.00071	.00102	.00139	1"
2	.00182	.00230	.00284	.00344	2
3	.00409	.00480	.00557	.00639	3
4	.00727	.00821	.00920	.01025	4
5	.01136	.01253	.01375	.01503	5
6	.01636	.01775	.01920	.02071	6
7	.02227	.02389	.02557	.02730	7
8	.02909	.03094	.03284	.03480	8
9	.03682	.03889	.04102	.04321	9
10	.04545	.04775	.05011	.05252	10
11	.05500	.05752	.06011	.06275	11
12	.06545	.06821	.07102	.07389	12
13	.07681	.07980	.08283	.08593	13
14	.08908	.09229	.09556	.09888	14
15	.10226	.10570	.10920	.11275	15
16	.11636	.12002	.12374	.12752	16
17	.13135	.13525	.13919	.14320	17
18	.14726	.15138	.15556	.15979	18
19	.16408	.16843	.17283	.17729	19
20	.18181	.18638	.19101	.19570	20
21	.20044	.20524	.21010	.21501	21
22	.21998	.22501	.23010	.23524	22
23	.24044	.24569	.25100	.25637	23
24	.26180	.26728	.27282	.27843	24
25	.28407	.28978	.29555	.30137	25
26	.30725	.31319	.31918	.32523	26
27	.33134	.33750	.34373	.35000	27
28	.35634	.36273	.36918	.37568	28
29	.38225	.38886	.39554	.40227	29
30	.40906	.41591	.42281	.42977	30

Cylinders with diameters 2 times larger than any in table, have 4 times greater capacity; 3 times larger, have 9 times greater capacity, etc.

Examples: How many cubic feet gas per minute pass through one double-acting compressor 8¾" diam. and 21" stroke, which runs at 60 revolutions per minute? .0348 × 21 × 2 × 60 = 87.696 cubic feet. Answer.

What is the volume of a L. P. cylinder, 54" diam. and 42" stroke?

$\frac{54}{2} = 27$, .33134 × 4 × 42 = 55.665 cubic feet. Answer.

Index

Compression Refrigerating

Chief Engi

PRESSURES

Time	COMPRESSOR		RECEIVER	BRINE COOLER	BRINE			STEAM	
	Rev.	High Ammonia	Ammonia	Ammonia	Low	High	Return	Boiler	Re
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									

ICE MAKING

Time	Cans Pulled	Tons Harvested	Tons to Kitchen	

TONNAGE OF MACHINE

Time	Rev. of Brine Pump × Average Range × Factor -- Tons Refrigeration
	H. P. Brine × × --
	L P " × × --
	Total Tonnage of Refrigerating Machine

Remarks

ant. The Plaza, N. Y.

rs Daily Log.

For 24 Hours Ending At..................................191

TEMPERATURES

Time	CONDENSERS			BRINE						
				HIGH PRESSURE			LOW PRESSURE			
	Water In	Water Out	Range	In	Out	Range	In	Out	Range	Ice Tank

METER READINGS

Time	
	Water to Machine
	Final
	Previous
	Cubic Ft. Used

BRINE PUMPS

Time	LOW PRESSURE				HIGH PRESSURE				STRENGTH OF BRINE	
	No.	Start	Stop	Rev.	No.	Start	Stop	Rev.	Time	At 60° F.
	1				1					
	2				2					

Tons to Restaurant	Tons to Bars

Date.......................................

REFRIGERATING ENGINEERS

ON DUTY

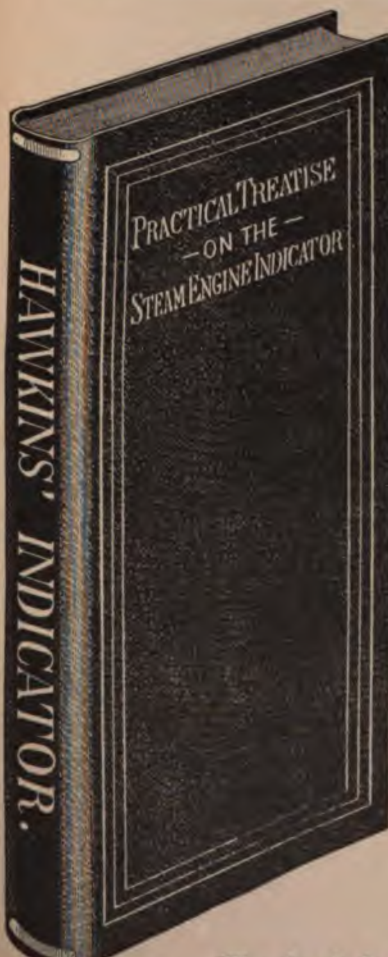
Time On	Time Off	Name

INDEX

Hawkins' on Indicator Cards, $1

Tells You How to Use an Indicator for Economical an
Correct Steam Engine Operation, Written so
You Can Understand.

THIS work is designed for the use of Erecting and Operat ing Engineers, Superintendents and Students of Stear Engineering, explaining, as i does, the economical use c steam.



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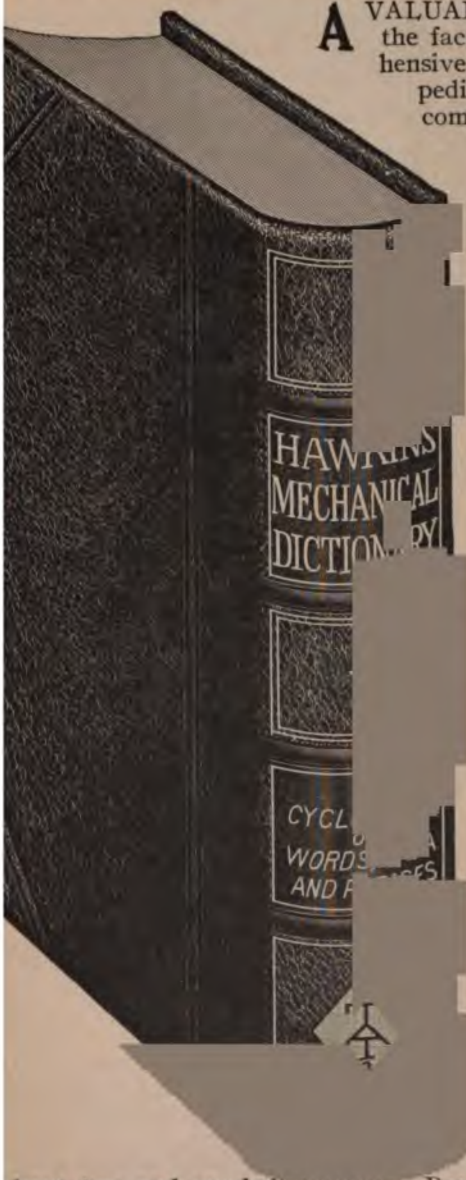

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